Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS GEO. L. GOODALE, JOHN TROWBRIDGE, W. G. FARLOW AND WM. M. DAVIS, OF CAMBRIDGE,

PROFESSORS A. E. VERRILL, HENRY S. WILLIAMS, AND L. V. PIRSSON, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA,
PROFESSOR H. A. ROWLAND, OF BALTIMORE,
MR. J. S. DILLER, OF WASHINGTON.

FOURTH SERIES.

VOL. X—[WHOLE NUMBER, CLX.]

No. 57.—SEPTEMBER, 1900.

NEW HAVEN, CONNECTICUT.
1900.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 125 TEMPLE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

WE DISCOVERED

That the material contained in those six cases of Cumberland minerals merited a fuller description than previous space in advertisements permitted. They were somewhat slow in arriving, and unpacking, washing and pricing takes time—so that July 16th rather than July 1st found them ready for your inspection. In spite of the continued high temperatures, we will endeavor to make our visitors as comfortable as ice-water and electric fans allow; however, such apparatus is not required to assure your appreciation of our stock of

Single Crystals. Many types of Barite with interesting modifications, coloring and translucency. The latter feature is perhaps most noticeable—unless it be the rare perfection of the individual specimens. No end of sizes, with prices attached which are veritably surprising. Fifty or seventy-five cents buys crystals which ordinarily would be hard to duplicate for twice the figures. Modified Calcites, long and slender, of beautiful quality, at similar rates. Complete cubes of Fluorite, from 1½ inches square up to four and five inches. These are by no means common, but our stock represents an assortment nowhere to be equalled.

Groups in all sizes, adapted for museum representation or private cabinets. Purple Fluors, many crystals measuring three to five inches across, in some instances coated with Quartz or Siderite, are among the most attractive of the larger specimens, although several of the "phantomed" Barite groups are of equal interest. Fluorites for open case display can be selected from a stock varying between $2.00 and $25.00, while Barites for similar purposes range from $1.50 to $20.00. Drawer specimens of either mineral, unusually choice examples, 50c. to $2.00.

Quartz after **Gypsum** with **Lutecite.** The pseudomorph is not the least interesting feature in connection with the previously described Lutecite specimens. Their locality, "Vaugirard, Paris," entitles them to some distinction, aside from the classification given in Dana's Appendix. $2.00 to $4.00.

URUGUAY "WATER STONES."

Several of these curious formations were recently purchased, and at the values affixed will quickly find buyers. In appearance they resemble an ordinary Chalcedony geode, with an almost botryoidal surface, beneath which can be distinguished the rapidly moving bubbles. As an inclusion they are highly desirable, for on slightly shaking, the liquid can be heard running in and out through the emptied cavities. They had been kept by the former owner for over seven years—and never changed the least. $6.00 and $8.00.

YOU ARE CORDIALLY INVITED

To call at our new store in Paris, if you intend visiting that city during the current year, or at some future date. Opening in May, we have endeavored to make our drawers and cases look as attractive as the fine stock and new furnishings will permit, especially for the many visitors expected during the Exposition Season. Within the grounds we are represented under the American Sections of the Mines and Mining Building and the Educational Departments (Groups XI. and XII.). Every consideration will be cheerfully shown to friends and patrons interested.

FOOTE MINERAL CO.,

FORMERLY DR. A. E. FOOTE,

WARREN M. FOOTE, Manager.

PHILADELPHIA,
1317 Arch Street.

PARIS,
24 Rue du Champ de Mars.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XVIII.—*On the Gas Thermometer at High Temperatures;* by LUDWIG HOLBORN and ARTHUR L. DAY.

Second Paper.

[Communication from the Physikalisch-Technische Reichsanstalt, Charlottenburg, Germany.]

IN a former paper* we described our measurements with the gas thermometer in some detail. The investigation was concerned principally with establishing the conditions under which this instrument may be used with certainty as a standard at high temperatures. We have shown that this is possible using pure nitrogen as the expanding gas in a bulb of platin-iridium, this material being much superior to the porcelain so long in use for the purpose, both in the accuracy of the results obtainable and the convenience in handling.

Since then the work has been continued in the direction indicated at the close of the previous paper. In order to obtain the full advantages of the exactness which the use of the platin-iridium bulb has rendered possible, the first step was to measure the undetermined coefficient of expansion of this metal at high temperatures. This was very necessary because the correction which the observations with the gas thermometer require on account of the expansion of the bulb increases more rapidly than the temperature to be measured. With the platin-iridium bulb, for instance, it amounts to 10° at 500°, 30° at 1000° and 40° at 1150°, while the increase in the coefficient of expansion with the temperature, which of course is not taken into account in the earlier paper, affects the measurement 1°, 5°, and 7° at the above temperatures respectively.

Secondly, the influence of the pressure which the expanding gas exerts on the glowing walls of the bulb was investigated

* Ludwig Holborn and Arthur L. Day, this Journal (IV), viii, 165, 1899.

by a simple method, and finally a second platin-iridium bulb with walls of double the thickness of the first was used in a somewhat different oven in verification of the earlier results. The use of the same thermo-element throughout enabled the observations to be compared with those of the previous series. The thermo-electric force of this element (platinum—platin-rhodium), like the others involving the use of combinations of metals of the platinum group, may be represented by an equation of the second degree within the limits of temperature covered by the investigation (250–1150°). The form of the curve is therefore known when such elements are calibrated at three known temperatures.

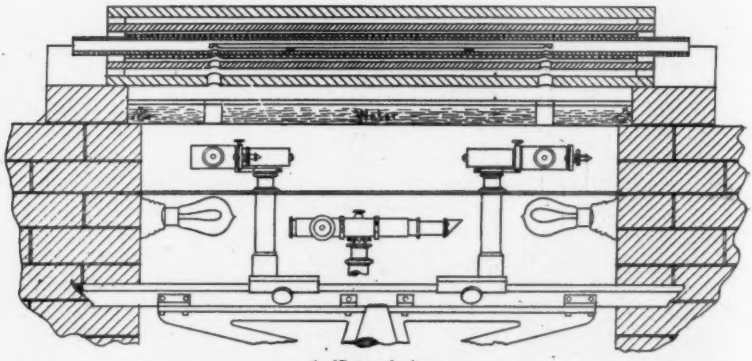
To render such calibration independent of the gas-thermometer, a series of melting points of pure metals was determined in which we took advantage of the opportunity to investigate rather carefully the conditions which may affect the melting temperature in certain cases.

To this is further added a chapter on the measurement with thermo-elements, the accuracy obtainable and their lasting qualities.

1. *Determination of the Expansion.*

To determine the expansion of the platin-iridium bulb, a bar of the same alloy (80 Pt, 20 Ir) was obtained, 500^{mm} in length and 5^{mm} in diameter and its linear expansion studied up to 1000°. In connection with this we also undertook the measurement of the expansion of several other substances at high tem-

1.



$\frac{1}{10}$ Natural size.

peratures and hope to communicate in detail the full results of the investigation at another time, restricting ourselves for the moment to such as are necessary to the discussion of the gas thermometer. Slight changes which the figures here commu-

nicated may undergo in the further investigation of the problem cannot sensibly affect the matter in hand.

The method may be described briefly as follows: The bar is laid for the measurement of its expansion symmetrically in an electrically heated fire-clay tube, 80^{cm} long, in which two lateral holes are bored 10^{mm} in diameter and 485^{mm} apart.

This tube is protected against loss of heat by radiation by two concentric fire-clay jackets with corresponding lateral openings, and the whole placed in a horizontal position upon two brick pillars in such a way that the openings are directed downward. Underneath these, two microscopes are mounted with the aid of which readings can be made of the position of certain marks cut upon a flat polished surface near the ends of the expanding bar.

The heating coil which is wound upon the innermost tube extends for a good distance beyond the ends of the bar so that the temperature opposite the opening differs in maximum only 10 per cent from that at the middle. On account of the increase in the coefficient of expansion with the temperature an average temperature for the bar is not sufficient if considerable local differences exist, hence it is eminently desirable that the differences of temperature along the bar be not too great. We are accordingly making an effort to improve upon our present coil in this direction in the hope that an even greater uniformity in the temperature distribution may be secured.

The microscopes were mounted upon sliding bases upon a long horizontal support and could be fixed in the proper positions with clamping screws. To protect them from the radiation of the oven a diaphragm through which water circulated constantly was introduced between.

With this apparatus the expansion was then measured with the eyepiece micrometers of the microscopes, the reading before heating being verified after the oven had cooled down again. No measurable displacement of the microscopes was observed throughout the series but displacements of the bar occurred now and then at the higher temperatures; symmetrical observations upon both ends, however, eliminate any error from this cause in the results.

The observations were usually made at 250°, 500°, 750° and 1000°, and for the same temperature upon different days agree to within $\pm 0{\cdot}01^{mm}$, whereby it should be remarked that one whole turn of the micrometer screw corresponds to about 1^{mm}.

The divisions, which were situated in the axis of the bar to diminish the effect of a possible slight bending or warping, were cut with the dividing engine, rather deep but with sharp edges, and rubbed with Parisian red (iron oxide). They were

illuminated from below with incandescent lamps. After the temperature has reached a bright red heat where the bar itself gives out light, the divisions still show very sharply by contrast with the polished metal surface as bright marks upon a dark ground.

But with the metals which oxidise and even with platin-iridium which tarnishes before reaching 1000°, it is better to illuminate the glowing rod from outside also. The divisions then appear as dark lines upon a bright ground exactly as at the lower temperatures.

The temperature of the bar thus heated was measured at nine different points with a thermo-element, both wires being insulated with thin porcelain tubes so that the junction could be brought to any desired point along its length.

Platin-iridium (80 Pt, 20 Ir).—The following values were obtained for the expansion λ_t of the platin-iridium bar, which together with a similar bar of pure platinum mentioned below, was kindly loaned by the firm of Heräus in Hanau:

	λ_t (mm)	
t	Observed.	Calculated.
250°	1·033	1·033
500	2·150	2·151
750	3·357	3·355
1000	4·645	4·645

The mean length included between the two groups of five divisions each at the two ends of the bar was 483·07^{mm} at 0°. From these figures the expansion λ of a bar of unit length at 0° may be represented by the formula

$$\lambda = [8198\,t + 1{\cdot}418\,t^2]\,10^{-9}.$$

Platinum.—We had no bar of the alloy 90 Pt, 10 Ir, of which the second bulb was made, but one of pure platinum was measured under the same conditions and yielded the following results, which we combined with the foregoing and used the mean for correcting the gas thermometer measurements made with the bulb of the lower alloy:

	λ_t (mm)	
t	Observed.	Calculated.
250°	1·114	1·113
500	2·309	2·304
750	3 570	3·571
1000	4·909	4·914

The length at 0° was 483·52^{mm} and the corresponding formula for a unit bar takes the form

$$\lambda = [8889\,t + 1{\cdot}274\,t^2]\,10^{-9}$$

The difference between the observed expansions and those calculated according to the formula amounts in both cases to less than $0{\cdot}01^{mm}$.

The largest measured difference between the observations upon the cold bars before and after heating to 1000° was $0{\cdot}025^{mm}$; it was generally much smaller.

Porcelain.—The expansion of Berlin porcelain was also measured upon a bar of similar dimensions—unglazed in order that it might afterward be used at still higher temperatures. Plane surfaces were ground upon each end in the same positions as for the metallic bars, and upon these, divisions about $0{\cdot}15^{mm}$ wide but very sharply defined were cut upon a lathe with a thin copper disc, five at each end. The readings at the highest temperature were at first somewhat difficult, for the divisions are but little brighter than the background. With illumination from outside, however, excellent readings could still be obtained after the candle power had been increased.

This bar had a mean length at 0° of $483{\cdot}47^{mm}$ and yielded the following results for the expansion:

	λ_a (mm)		λ(mm)
t	Observed.	Calculated.	
250°	0·382	0·391	0·790
375	0·628	0·612	1·299
500	0·845	0·850	1·749
625	1·093	1·105	2·261
750	1·307	(1·377)	2·703
875	1·615	(1·666)	3·340
1000	1 977	(1·972)	4·089

Observations were made with the porcelain bar at temperatures between the original four, when it was found that the observed expansions could not be represented by a curve of the second degree. The following formula is approximately true between 250° and 625°,

$$\lambda = [2954\,t + 1{\cdot}125\,t^2]\,10^{-9}$$

and yields the observed value again at 1000°, while for 750° and 875° the differences are considerably larger than the errors of observation. Below 250° also the values obtained from the formula are too large. The coefficient of expansion clearly increases more rapidly after red heat is reached than below 500°, and for the interval between remains nearly constant. The observed value at 1000° coincides with the calculated value again, which shows this temperature to be the point of intersection of two curves.

It may be further remarked that the various series of observations, after the preliminary heating to remove any tension

remaining from the grinding, agree quite as well for porcelain as for the metals. These observations were all made with a rising temperature, however, and it is not impossible that different values would be obtained for the expansion of porcelain if the temperatures observed were approached from the other direction, i. e. in the order 1000°, 875°, 750°, etc. It also remains to be investigated what differences exist between different bars of the same manufacture.

The expansion of Berlin porcelain formed the subject of an earlier investigation by Holborn and Wien,* who heated porcelain plates 9^{cm} in length in a gas furnace and measured them at the temperatures 550° and 1050° nearly. The mean value then arrived at, $44 \cdot 10^{-7}$ for the linear expansion coefficient, agrees with the present value at the higher temperature within the limits of accuracy then obtainable; at the lower temperature the earlier value is too large.

More recently Bedford† determined the expansion of French porcelain (Bayeux) between 0° and 800°. His formula is

$$\lambda = [3425t + 1 \cdot 07t^2]\, 10^{-9}$$

A comparison with our results is not instructive, however, for the expansions of porcelains from entirely different sources are not properly comparable.

Our measurements with the gas thermometer and porcelain bulbs, for the calculation of which the Holborn and Wien value was used, require only a slight correction for the new determination of the expansion, partly because the absolute expansion is very small and partly because the use of too large a value for the bulb expansion between 0° and 100° makes it also necessary to correct (diminish) the coefficient of expansion of the gas about $\frac{1}{700}$. The required correction, therefore, remains less than 1° for the whole range from 500° to 1000°.

Jena Glass 59^{III}.—For the measurement with the gas thermometer below 500° a bulb of Jena glass 59^{III} and a nitre bath were used. We have, therefore, undertaken to measure the expansion of this material up to 500°, but the results which have so far been obtained only serve to emphasize how much depends upon the way the glass is treated. We were able, however, to establish the fact that the mean error of the gas thermometer observations in this region, $\pm$ 0·5°, is not exceeded in assuming for all temperatures up to 500° the constant value $18 \cdot 10^{-6}$. For more accurate measurements it is certainly advisable to employ the platin-iridium bulb for these temperatures also, the expansion of which is much better defined. In the nitre bath it will be necessary to protect it with a thin glass tube, however, as the bath becomes alkaline with use.

* L. Holborn and W. Wien, Wied. Ann., xlvii, 121, 1892.
† T. G. Bedford, Phil. Mag. V, xlix, 90, 1900.

2. *Influence of Pressure on the Gas Thermometer Bulb.*

At the highest temperatures measured the inside pressure in the platin-iridium bulb exceeded that outside by nearly an atmosphere. Although no permanent change in the volume of the bulb after heating could be detected, it seemed, nevertheless, not impossible that a temporary yielding of the glowing walls under the comparatively high pressure might take place. We have investigated this question by redetermining the higher temperatures with a much diminished pressure.

This was accomplished by allowing a portion of the expanding gas to pass over into the closed tube of the manometer, thus varying pressure and volume simultaneously. The expansion-coefficient of the gas suffers a small change thereby which we estimated to be about 0·1 per cent and therefore neglected it.

The closed manometer tube had already been provided with two points (see first paper—loc. cit.) at which readings could be made for volumetric purposes, so that by bringing the mercury tangent to the lower point a definite volume could be added to that of the bulb. To enable a more accurate measurement of the temperature of this supplementary volume to be obtained than was possible with the small thermometer in the cap, a second and more sensitive thermometer was fastened to the tube and the whole carefully packed in a thick layer of cotton batting containing only the two small openings necessary to make the readings above and below.

As a rule the observations were made in sets of three, the first and last with the mercury adjusted to the lower, the second to the upper point. Since it was necessary to wait some time between observations until the temperature conditions in the manometer became uniform, the temperature in the oven had opportunity to change a few degrees. These changes (δ) were measured with the thermo-elements. The supplementary volume between the two points was measured by weighing the mercury required to fill it, the results being as follows:

50·630$^{cm^3}$
50·609
50·641
50·658

Mean 50·635$^{cm^3}$

The differences between the determinations are largely due to an imperfectly formed meniscus at the lower point, the adjustment being necessarily made with a falling column as the mercury was drawn off through a fine capillary tube. The adjustment with a rising column as used for the temperature measurements gives much more exact results. Also the deter-

mination of the distance between the two points, 161·60^{mm} contained variations of only 0·02^{mm} in the individual readings. An error of 0·1 per cent in the determination of the supplementary volume would cause an error of 1° in the temperature at 1000° as determined at the lower point.

For the verification of the method several measurements of the volume of the bulb at 0° were made. For the first platinum bulb the determination by filling with water and weighing yielded 208·49$^{cm^3}$, the volumetric determination 208·45 and 208·51$^{cm^3}$; for the second bulb the results obtained by the two methods were 195·87 and 195·91$^{cm^3}$ respectively.

Table XII contains the temperature measurements at the two different pressures. H and t represent the pressure measured upon barometer and manometer, and the temperature calculated from it for the readings made at the uppermost point; H′ and $t'-\delta$, the corresponding magnitudes for the readings

TABLE XII.

1899	H (mm.)	t	H′ (mm.)	$t'-\delta$	δ	$t-t'$
July 22	871·71	553·0°	524·13	550·9°	+2·0°	+0·1°
			526·38	556·6	−3·4	−0·2
	877·37	558·7	526·80	557·8	+1·5	−0·6
			528·35	562·0	−2·9	−0·4
	1339·50	1022·7	663·06	1015·4	+6·3	+1·0
			666·71	1030·1	−7·6	+0·2
Aug. 2	848·68	531·1	514·76	527·9	+2·5	+0·7
			517·07	533·8	−2·9	+0·2
	855·11	537·4	517·76	535·5	+1·6	+0·3
			519·05	539·1	−1·6	−0·1
	1047·86	728·2	581·57	721·9	+5·3	+1·0
			585·81	734·9	−7·3	+0·6
	1055·69	736·1	585·80	734·8	+1·1	+0·2
			586·89	737·9	−1·9	+0·1
Aug. 3	952·97	633·9	551·09	629·4	+3·5	+1·0
			558·78	651·4	−18·4	+0·9
	974·06	654·8	559·11	652·5	+1·6	+0·7
			560·58	656·7	−2·4	+0·5
	1242·43	924·5	638·41	921·4	+1·5	+1·6
			639·87	926·7	−3·1	+0·9
	1243·62	925·8	639·62	925·5	−0·6	+0·9
			639·63	925·6	−0·6	+0·8

and $t'-\delta$, the corresponding magnitudes for the readings

below. If to $t' - \delta$ the change in the oven temperature δ be added, the results contained in the column $t - t'$ or the difference between the results obtained at the two pressures is obtained. The mean value of this difference is $\pm 0{\cdot}7°$ and exceeds $1{\cdot}0°$ only in a single instance.

It follows from this that within the given limits of accuracy, the measurements with the gas thermometer equipped with the platin-iridium bulb were not disturbed by the pressure upon the walls of the hot bulb. The initial pressure of the gas at 0° was $294{\cdot}40^{mm}$, nearly the same as in the earlier measurements, and its coefficient of expansion 0·003666.

It has been suggested that this method be employed for obtaining the volume of the bulb at high known temperatures. It would then be possible to arrive at its coefficient of expansion in this way. In addition to the usual equation for the calculation of the temperature with constant volume,

$$\frac{HV}{1+at} = H_0 V_0$$

a second relation is, to be sure, obtainable

$$H'\left(\frac{V}{1+at} + \frac{V_t}{1+at_t}\right) = H_0 V_0$$

if t_t be used to represent the temperature of the supplementary volume V_t. The equations are nevertheless not independent of each other and are therefore not sufficient for the determination of the two unknown quantities V and t.

3. *Comparison of the Thermo-element with the Gas Thermometer.*

Second Platin-iridium Bulb.—The second platin-iridium bulb had nearly the same form and size as the first. It was, however, made from the alloy 90 Pt. 10 Ir., and its walls (1^{mm}) were twice as thick as those of the earlier bulb. Its volume at 0° was $195{\cdot}87^{cm^3}$.

After being boiled with concentrated nitric acid and several times rinsed with distilled water the bulb was carefully dried and attached to the manometer. Then it was evacuated with a mercury pump and maintained for several hours at a temperature of 1300°, being "rinsed" from time to time with fresh nitrogen and again evacuated. The gas for the final filling was also admitted at the high temperature and the exact pressure regulated after the bulb had cooled.

The new bulb was used for several series of measurements and proved to be quite as satisfactory as the old. The gas pressure at 0° remained constant to within $0{\cdot}1^{mm}$ throughout.

The comparisons of the gas thermometer and the thermo-element T_2 which are contained in Table XIII agree among themselves exceedingly well and with the earlier comparisons also. The differences, which amount to about 1·0°, are of the same order of magnitude as in all the other measurements made under the given conditions, the bulb with its extended volume and the minute thermo-electric junction being contained in an air bath. The highest temperatures are most favorable in this respect, as the radiation acts most strongly there to equalize the temperature distribution.

Below 500° where the air bath gave place to nitre, the uniformity is also greater of course.

The conditions under which the second bulb was heated were also considerably varied in order that the substantiation of the earlier results might be as complete as possible. The observations under "October 12" in the table, for example, were made with the bulb in the same oven which had served for the measurements with the first bulb, the others in a newer and larger one, but with two different heating coils on the different days—both wound logarithmically as described in the former paper. The tubes carrying these new coils were 42^{cm} long and 6^{cm} inside diameter while the older one was only 35^{cm} long and 4·8^{cm} in diameter. The fire-clay jackets were also correspondingly larger.

TABLE XIII.

Platin-iridium Bulb No. II (90Pt, 10Ir) Gas-Nitrogen.

V_0=195·87cm^3 V_e=0·904cm^3 H_0=276·35mm α=0·003666

1899	t	e_2(MV)	Obs.—Calcul.	1899	t	e_2(MV)	Obs.—Calcul.
Oct. 9	562·1°	4759	0·0°	Oct. 12	822·9°	7497	−1·5
	571·7	4861	−0·5		822·5	7496	−1·9
	573·2	4877	−0·6		1093·5	10558	−0·7
	829·5	7568	−1·5		1096·1	10598	−1·5
	1080·9	10423	−1·8		1097·4	10616	−1·7
" 12	552·0	4668	−1·0	" 21	669·1	5836	+1·1
	552·2	4670	−1·0		917·4	8526	−0·2
	552·6	4674	−1·0		1063·3	10189	+0·5
	821·2	7478	−1·5				

In Table XIII, t represents the temperature observed with the gas thermometer, e_2 the thermo-electric force of the element T_2 in microvolts. The last column (Obs.—Calcul.) contains the difference between t and the temperature in degrees calculated from the curve for e_2. This curve will be referred to again further on.

The Observations with the first Platin-iridium Bulb.—The earlier observations (loc. cit. Tab. IX, p. 189) with the first bulb (80 Pt, 20 Ir), which were calculated with a constant coefficient of expansion, can now be corrected for the increase in the expansion with the temperature. The corrected values are contained in Table XIV, the numbers printed in italics in Table IX being here omitted. They were made with a uniformly wound oven coil, and a comparatively large (former paper, Table VIII, p. 189) fall in temperature along the bulb, roughly corrected with the help of the thermo-elements.

TABLE XIV.

Platin-iridium Bulb I (80Pt, 20Ir). Gas-Nitrogen.

After filling.	t	e_2(MV)	Obs.—Calcul.	After filling.	t	e_2(MV)	Obs.—Calcul.
2d day	529·1°	4429	+0·3°	22d day	1052·8°	10073	−0·1°
	614·8	5289	+0·1		1102·5	10653	+0·4
	1008·8	9555	+0·6				
				24th "	541·2	4552	+0·1
20th "	625·6	5401	−0·1		542·8	4569	−0·2
	812·1	7356	+0·6		615·5	5297	0·0
	907·3	8396	+1·2		717·3	6343	+0·7
	1014·8	9622	+0·9		814·3	7385	−0·2
	1113·9	10770	+1·7		919·7	8550	+0·2
					1017·6	9661	+0·1
22d "	511·8	4252	+1·1		1106·6	10700	+0·4
	512·7	4268	+0·2				
	551·5	4655	−0·2	25th "	516·4	4304	+0·2
	659·3	5754	−0·8		616·3	5303	−0·1
	703·8	6217	−0·9		721·3	6382	+0·7
	757·0	6775	−0·5		821·9	7462	+1·6
	859·4	7881	−0·3		913·4	8458	+1·8
	949·2	8890	−0·6		1026·0	9756	+0·5
	1001·5	9496	−1·6		1134·5	11031	+0·7
	1050·4	10044	−0·1				

The temperatures t are raised by the new coefficient of expansion 0·7° at 500°, 4·9° at 1000° and 7·5° at 1150°.

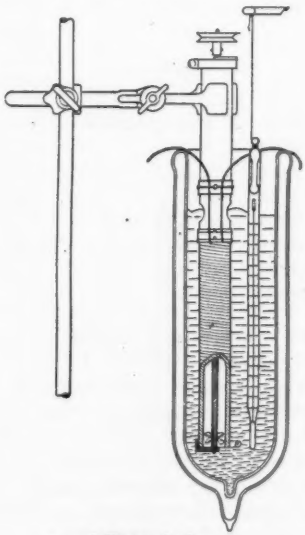
In the recalculation a small correction has also been added for the slight over-compensation of the heating coil (Table VIII)—13 microvolts at 500°, and 5 at 1150°. This corresponds to the measured temperature distribution according to which the junction of T_2 opposite the middle of the bulb reads smaller than the integral temperature—at 620° 1·2° smaller, at 820° 1·0°, at 1010° 0·5° and at 1150° 0·4°.

Observations below 500°.—After the observations in the electric oven between 500° and 1150° were completed, the thermo-element T_2 was compared with the gas thermometer

equipped with a bulb of Jena glass 59^{III} between 250° and 500° in a nitre bath. These observations were designed partly to verify the earlier observations below 500°, with which the element T_2 was connected only indirectly by comparison with T_1; and partly to enable us to compare the absolute values obtained from observations in the nitre bath and in the electrically heated air bath.

This nitre bath was considerably smaller than the one used for the earlier observations and was heated electrically, whereby we were enabled to secure constant temperatures more quickly and more exactly. A wrought iron cylinder 12^{cm} in diameter, such as is used for the transportation of mercury, was cut off at a height of 27^{cm} and fitted with a cover 2^{cm} thick, which carried a turbine driven by an electric motor for stirring. The heating coil was of bare constantan wire 1·5^{mm} in diameter wound in two parallel coils upon the cylinder, the insulation being provided by a layer of asbestos board, and held in place by smearing with clay. The whole was enclosed in a larger fire-clay jacket and the space between closed in with asbestos wool, giving a layer of air a centimeter or more thick about the coil. This bath can be used up to 700°.

2.



⅓ Natural size.

For temperatures below 300° where insulating liquids may be used for the baths, an arrangement which did us exceedingly good service certainly deserves mention in passing. A

cylindrical glass vessel, with double walls enclosing a vacuum, such as is commonly used for liquid air (Prof. Dewar's design), was filled with olive oil. Into the oil dipped a porcelain tube with two spiral furrows upon the outer surface, carrying coils of bare constantan wire. Inside the tube a turbine was inserted and held in place above and below with brass clamping rings. The stirrer and heating coil were thus in one piece and could be introduced into any insulating bath at pleasure. A vessel with a vacuum jacket is preferable however, on account of the very small quantity of electrical energy required to heat it, even when the walls are left unsilvered for reading a completely immersed thermometer. With 1·2 l. of oil only 100 watts were necessary to maintain a temperature of 250°. Although in using this apparatus we did not have an accident from explosion of the vessel, still, as this now and then occurs with such vessels at low temperatures without any apparent cause, it is well to make provision against possible personal injury in such an event. Table XV contains the comparison of thermo-element and gas thermometer in the nitre bath. The bulb was filled with nitrogen under a pressure of 471·84^{mm} at 0°.

TABLE XV.

Observations in the Nitre Bath.

	t	e_2 (MV)	Obs.—Calcul.		t	e_2 (MV)	Obs.—Calcul.
Feb. 6	340·7°	2639	−0·8°	Feb. 8	395·8°	3153	−0·8°
	340·5	2635	−0·5		395·8	3151	−0·6
	387·5	3076	−0·9		492·6	4082	−0·7
	386·9	3071	−1·0		492·8	4084	−0·7
	439·8	3573	−1·0	March 29	359·6	2803	+0·4
	439·8	3572	−0·9		359·5	2802	+0·4
	501·3	4171	−1·3		400·5	3195	−0·6
	500·9	4168	−1·4		402·4	3217	−1·0
Feb. 8	267·4	1970	−0·6		498·5	4140	−1·0
	291·6	2191	−0·8		498·3	4139	−1·1
	291·7	2193	−0·9				

4. *Formulae for Thermo-elements.*

In a previous paper* we were able to show that the relation between the thermo-electric force and the temperature in metals of the platinum group together with gold and silver could be represented within wide limits with an accuracy of ± 1° by a function of the second degree.

* Ludwig Holborn and Arthur L. Day, this Journal (IV), viii, 46, 1899.

The measurements made at that time were upon wires of pure rhodium, iridium, palladium, gold and silver together with alloys of platinum with palladium and ruthenium, whose thermo-electric force referred to pure platinum was measured up to 1300°. The elements with palladium or palladium alloys differed from the others in that the range within which the parabolic formula applies is smaller.

The formula for the normal element T_2 derived from the comparisons with the gas thermometer follows, together with certain of the others; those metals being chosen which are best suited to the measurement of high temperatures and which offer a basis for exterpolation.

These have been compared with the normal element from 50° to 50° approximately and the thermo-electric forces corresponding to the exact temperature intervals as contained in Table XVI, obtained from the observed data by graphical interpolation.

Since the publication of the earlier paper some observations above 1300° have been added with the aid of an oven equipped with a coil of platin-iridium wire.

Normal Element Pt—90 Pt, 10 Rh.—The thermo-electric force e_2 in microvolts of the platinum—platin-rhodium standard element T_2 is given by the following equation from 250° upwards

$$e_2 = -310 + 8{\cdot}048\,t + 0{\cdot}00172\,t^2$$

when the hot junction is maintained at the temperature $t°$ and the cold junction at 0°. The formula is based upon the observations with the platin-iridium bulb above 500° and with the glass bulb and nitre bath below, as contained in Tables XIII, XIV and XV. In the columns "Obs.—Calcul." of these tables will be found the differences between the observed values and those obtained from the formula.

It will be recalled that the element T_1 was compared (first paper, Tables I to VII) above 500° with the gas thermometer equipped with porcelain bulbs. These observations differ among themselves somewhat, due in part to the behavior of the porcelain bulbs and in part to the less perfect conditions of measurement then obtaining. In the normal curve these observations are therefore not included, the curve being based entirely upon the temperatures measured with T_2 and the platin-iridium and glass bulbs. It is nevertheless not without interest to compare the temperatures obtained with T_1 and the porcelain bulbs, with the later ones.

This may be done by referring the normal values for T_1 (Table II former paper) to those of T_2, by adding the differences $T_2 - T_1$ (Table XI, former paper) which were obtained by

direct comparison of the two elements, or in other words if T_2 be referred to the observations made with the gas thermometer as used with porcelain bulbs.

In Table XVI in the first column the values of the electromotive force for T_2 calculated from the formula are contained. The column Δ contains the differences between these values and those obtained from $T_1+(T_2-T_1)$ as suggested above. If now these values of Δ be compared with the earlier ones (Table XI, former paper) it will be seen that the differences have become very small now that the proper expansion coefficients of both porcelain and platin-iridium have been applied.

From this the conclusion follows that the porcelain bulbs lead to substantially the same results as the platin-iridium as long as the former are not used above 1100°. Under these conditions of course only bulbs glazed inside and out need be used, as the glazing does not melt up to that point.

Regarding the precautions necessary to be observed in the use of porcelain bulbs and the degree of accuracy obtained in temperature measurements with them, reference is made to the former communication.

Element Pt–90 Pt, 10 Ru.—The element platinum—platin-ruthenium follows a curve very similar to that of the normal element. Its equation is

$$e_5 = -359 + 9{\cdot}260\,t + 0{\cdot}00150\,t^2$$

Element Pt–Ir.—For the element platin-iridium a formula has also been calculated which like the others holds from about 300° on. Like the following curves it is based on the thermo-electric force of two pure metals and possesses a much greater curvature then those of the alloys. It is—

$$e_4 = -248 + 7{\cdot}282\,t + 0{\cdot}00554\,t^2$$

Element Pt–Rh.—For the combination platinum-rhodium two specimens of pure rhodium were at our disposal. The first was from Heräus, the second was especially prepared in the *Reichsanstalt.* The two formulae are

$$e_5 = -228 + 7{\cdot}230\,t + 0{\cdot}00660\,t^2$$
$$e_6 = -235 + 7{\cdot}410\,t + 0{\cdot}00660\,t^2$$

The second equation is derived under the assumption that the differences between the two curves e_5 and e_6 can be represented by a linear relation. The observed results between 300° and 1150°—the range of the gas thermometer—are made the basis for the derivation of this as well as of the other formulae.

Table XVI contains the observations upon these elements as well as the differences between them and the values calculated from the above formulae in microvolts and degrees.

TABLE XVI.

t	Pt − 90Pt, 10Rh.			Pt − 90Pt, 10Ru.			Pt − Ir			Pt − Rh_1			Pt − Rh_2			t
	e_2 Calcul. MV	Δ		e_3 Obs. MV	Obs.—Calcul.		e_4 Obs. MV	Obs.—Calcul.		e_5 Obs. MV	Obs.—Calcul.		e_6 Obs. MV	Obs.—Calcul.		
		MV	Degrees		MV	Degrees		MV	Degrees		MV	Degrees		MV	Degrees	
250°	1810	−10	−1·1°	2062	+12	+1·2°	1966	+47	+4·7°	2004	+12	+1·1°	2042	+12	+1·1°	250°
300	2260	+ 3	+0·3	2550	− 4	−0·4	2474	+39	+3·7	2536	+ 1	+0·1	2580	− 2	−0·2	300
350	2718	+ 9	+1·0	3056	−10	−1·0	3002	+23	+2·1	3112	+ 1	+0·1	3160	− 7	−0·6	350
400	3185	+ 9	+1·0	3580	− 5	−0·5	3550	− 1	−0·1	3714	− 6	−0·5	3780	− 5	−0·4	400
450	3661	+11	+1·1	4112	+ 1	+0·1	4156	+ 5	+0·4	4362	0	0·0	4432	− 4	−0·3	450
500	4145	+ 5	+0·5	4646	0	0·0	4778	0	0·0	5032	− 5	−0·4	5118	− 2	−0·2	500
550	4638	+ 4	+0·4	5184	− 4	−0·4	5424	− 9	−0·7	5744	− 1	−0·1	5834	− 3	−0·2	550
600	5139	+ 3	+0·3	5738	+ 1	+0·1	6102	−14	−1·0	6484	− 2	−0·2	6582	− 5	−0·3	600
650	5649	− 1	−0·1	6290	− 4	−0·4	6810	−16	−1·1	7260	0	0·0	7372	+ 2	+0·1	650
700	6168	− 6	−0·6	6860	+ 2	+0·2	7564	0	0·0	8076	+ 9	+0·6	8192	+ 6	+0·4	700
750	6695	− 9	−0·8	7430	0	0·0	8320	−10	−0·7	8906	− 1	−0·1	9038	+ 3	+0·2	750
800	7231	−10	−0 9	8012	+ 3	+0·3	9116	− 7	−0·4	9790	+10	+0·6	9928	+11	+0·6	800
850	7775	−11	−1·0	8596	0	0·0	9948	+ 4	+0·2	10688	+ 2	+0·1	10840	+ 8	+0·4	850
900	8328	−11	−1·0	9196	+ 6	+0·5	10798	+ 5	+0·3	11644	+19	+1·0	11802	+22	+1·1	900
950	8890	− 9	−0·8	9804	+ 8	+0·7	11670	0	0·0	12614	+17	+0·9	12782	+21	+1·1	950
1000	9460	− 8	−0·7	10410	+ 9	+0·7	12588	+14	+0·8	13600	− 2	−0·1	13774	− 1	−0·1	1000
1050	10039	0	0·0	11018	0	0·0	13518	+12	+0·6	14616	−24	−1·1	14800	−22	−1·0	1050
1100	10626	+13	+1·1	11646	+ 4	+0·4	14482	+16	+0·8	15692	−19	−0·9	15884	−18	−0·8	1100
1150	11222			12274	0	0·0	15462	+ 9	+0·5	16800	−15	−0·7	16976	−39	−1·7	1150
1200	11827			12918	+ 5	+0·4	16482	+21	+1·0	17946	− 6	−0·3	18130	−31	−1·3	1200
1250	12440			13556	− 4	−0·3	17498	− 5	−0·2	19106	−17	−0·7	19280	−60	−2·5	1250
1300	13062			14208	− 6	−0·5	18580	+ 7	+0·3	20314	−11	−0·5	20492	−60	−2·5	1300
1350	13692			14864	−12	−0·9	19662	− 9	−0·4	21556	− 5	−0·2	21728	−69	−2·7	1350
1400	14331			15528	−17	−1·3	20766	−20	−0·9	22800	−30	−1·2	22988	−87	−3·4	1400
1450	14979			16220	− 2	−0·2	21904	−35	−1·5	24136	+ 4	+0·2	24276	−110	−4·1	1450
1500	15635			16914	+ 8	+0·6	23056	−74	−3·0	25486	+19	+0·7	25684	−46	−1·7	1500

Attention should perhaps be called to the fact that in the comparisons between these elements and the normal element, different sections of the same curve are separated in particular cases by considerable intervals of time so that the distribution of temperature from junction to junction was not always the same even through the observations of a single series. Small consistent differences between "Obs." and "Calcul." may be fairly attributed to this cause, though for the temperature range 300° to 1150° when the gas thermometer was used, the differences rarely exceed 1°; above 1150° where the figures are based upon an exterpolation of the formula for T_s they are sometimes larger, though nowhere exceeding 5°.

5. *Melting Points of Metals.*

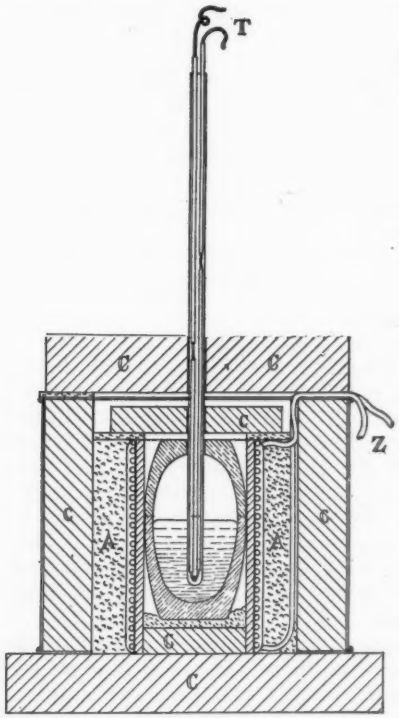
To render the calibration of thermo elements independent of the gas thermometer we have determined the melting points of various metals lying between 300° and 1100°. Two methods were used: According to the first, a short wire (about 1^{cm} long) of the metal to be melted was introduced into the hot junction of the thermo-element itself, and the thermo-electric force at the moment of the melting and consequent interruption of the circuit, observed. This method is simple but leads easily to doubtful results if the melting point is at all affected by the surrounding atmosphere, as is the case with most of the metals which oxidize in air. The element also becomes considerably shortened by the continual cutting off of the drop of melted metal after the observations and renewing the junction.

By the second method a larger quantity of metal is melted in a crucible and the thermo-element, protected by light porcelain tubes, inserted. When the heating is properly regulated the beginning of the melting or freezing point is readily recognizable as the temperature remains stationary for a considerable length of time. In the following, the words "wire method" and "crucible method" may serve to distinguish the two processes.

For the latter method the apparatus was arranged as indicated in fig. 3. A porcelain or graphite crucible is contained within a short fire-clay tube carrying a coil of bare nickel wire whose separate turns were insulated by smearing with clay. The whole is protected against loss of heat by a layer of loose asbestos A and a thick protecting tube also of fire-clay. The wires of the thermo element are insulated from each other by means of thin porcelain tubes and from the molten metal by a somewhat thicker tube of the same material, 5^{mm} in inside diameter and $1{\cdot}5^{mm}$ in thickness, which dipped at least 4^{cm} into

the melting metal (1^{cm} from the bottom of the crucible) and was clamped in position there.

3.



‡ Natural size.

The figure shows the oven with a graphite crucible in position and a second slightly smaller one with a hole bored in the bottom inverted over it as a cover.

The porcelain crucibles were similar in size and form, 1^{mm} thick and without cover.

Inasmuch as the electric heating furnished a much more uniform distribution of temperature than the gas oven and as no systematic differences between the melting and freezing temperatures were observed even with the most varied conditions of current and quantity of metal, we did not attempt to stir the metals in general. Only in one section of the observations with silver an effort was made to expose the melted metal more thoroughly to the air by stirring.

In the preliminary experiments the coil was wound directly upon a crucible of fire clay, but that was soon given up—first

because the clay was too porous to hold the melted metal in all cases (molten Cu for instance penetrated the wall and short-circuited a section of the coil), and second, the change from one crucible to another which happened nearly every day was much more convenient with the coil wound upon a separate tube. This oven consumed about 600 watts at 1000°

Some caution was necessary in heating up to the highest melting point (copper), otherwise the oven coil (1^{mm} in diameter) burned out—its renewal is a simple matter however.

For the temperature measurement thermo-elements were used which were cut from the same wire as T_2 and which have shown themselves to be perfectly identical with it in their results. Temperatures above 500° are derived from the normal curve (Table XVI) and below from the measurements in the nitre bath.

In each determination the thermo-electric force was observed from minute to minute and afterward plotted as a function of the time (mentioned hereafter as the "time curve"). A change of 10 microvolts could be compensated directly on the compensation apparatus by inserting 0·1 ohm. Smaller differences were interpolated from the galvanometer deflection, one scale division corresponding to from 0·5 to 1·4 microvolts according to the resistance in the branch circuit.

The accuracy of the crucible method is only limited by the accuracy with which it is possible to measure with the thermo-element, in regard to which more will be said further on. The wire method is less exact because the interruption of the circuit which indicates the melting point is not independent of any slight tension which may exist in the wires of the thermo-element, particularly the platin-rhodium wire—a factor which varies from one observation to another.

The highest temperatures observed for a particular metal by this method may therefore be expected to come nearest the truth. The inserted wire may even at times be seen to break just before the real melting takes place.

Gold.—The melting point of gold was determined by the wire method only. Two different specimens of gold had been placed at our disposal, one (I) from the *Gold und Silber Scheideanstalt* in Frankfurt-am-Main, the other (II) specially prepared and purified in the Reichsanstalt. No difference could be detected in their melting temperature.

The observations on the first two days (following table) were made in the gas thermometer oven, the others in the small oven used for the determinations by the crucible method (fig. 3) in which an empty crucible had been placed.

The arrangement of the thermo-element in the latter case was the same as above described for the crucible method with the omission of the porcelain protecting tube. The heating

was so regulated that the slowly rising temperature could be easily observed at any time. It was even possible to observe the stationary temperature at the melting point just before the interruption of the circuit. The observed melting temperatures in microvolts and in degrees follow:

		Microvolts.	Degrees.
Oct. 17	(I)	10209	1064·5°
		10209	1064·5
		10206	1064·2
		10208	1064·4
Oct. 18	(II)	10202	1063·9
		10201	1063·8
Nov. 15	(II)	10211	1064·6
		10211	1064·6
		10211	1064·6
Jan. 2	(II)	10190	1062·9
		10190	1062·9
		10200	1063·7
		10189	1062·8
Jan. 3	(II)	10203	1064·0
		10197	1063·5
		10213	1064·8

The mean is 1064·0° ± 0·6°.

Silver— Wire Method.—The melting point of silver was also first determined by the wire method and two specimens were used, both from the Frankfurt *Scheideanstalt.* One of these was in the form of wire 0·5^{mm} and 0·25^{mm} in diameter and the other a piece of sheet silver 0·25^{mm} in thickness, from which thin strips were cut and inserted in the junction of the element. Here again no difference in the melting temperature of the two specimens could be established. The same ovens were used as for the gold determination. The results follow:

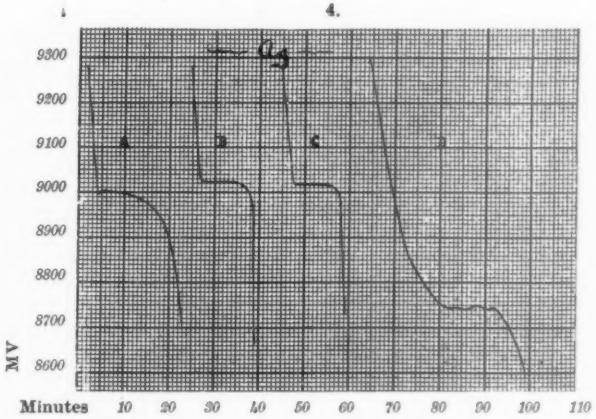
	Microvolts.	Degrees.
Sept. 25	8928	953·3°
	8936	954·0
Oct. 16	8937	954·1
	8922	952·8
	8922	952·8
Oct. 18	8914	952·1
	8927	953·3
	8930	953·5
	8935	953·9
Nov. 15	8939	954·3
	8958	956·0
	8925	953·1
	8941	954·5
	8924	953·0

The mean is 953·6° with a mean error of ± 0·9°.

Callendar as well as Heycock and Neville* have called attention to the fact that silver in an oxidizing atmosphere melts and solidifies at a lower temperature than in a reducing atmosphere, the difference being caused by the fact that silver absorbs oxygen in melting which is given off again below the melting temperature with considerable violence ("spitting").

Silver—Crucible Method.—In order to ascertain whether the melting point as determined by the wire method differs from the normal melting temperature we made determinations of it by the crucible method also.

(1) *In an Oxidizing Atmosphere.*—At first the silver was melted in an open porcelain crucible without stirring. Under these conditions the results differed from those with other metals in that the silver showed no definite melting temperature. In melting as well as in solidifying the "time curve" takes the form A (fig. 4), i. e. throughout its length it contains



no horizontal section but falls or rises slowly over an interval of 6° to 8°, between which limits one point may be assumed as the melting point nearly as well as another. After substituting mica sheets for the clay oven-covers so as to be able to see the metal during the process, it was observed that it remained liquid through the greater part of this interval. The melting and solidifying occurred at about 954·5° (8940 microvolts). It may be added that the substitution of three mica covers separated by air layers, for the two clay covers, produced no essential change in the conditions within the oven.

If the thermo-element with its protecting tube were moved about or the liquid metal otherwise stirred, the form of the

* C. T. Heycock and F. H. Neville, Journ. Chem. Soc., 1895, 160 and 1024.

time curve remained in general the same except perhaps that the limits of the slow rise or fall of the temperature were moved closer together, and if the stirring was energetic, could be lowered some degrees.

Table XVII contains a number of results partly with stirring and partly without. G indicates the weight of the melted metal in grams, t_1 and t_2 the upper and lower limits of the slow change of temperature about the melting point, and t their arithmetical mean. The letters F and M distinguish freezing and melting points. The strength of the oven current i may serve to give an idea of the comparative expenditure of energy in the different determinations though only a rough one, as the resistance of the coil on different days was not always the same. The mean value of t for the observations where the metal was stirred is 954·9° and differs only 1·3° from the result

TABLE XVII.

Melting Point of Silver in Air.

1899. Novem'r.	G (gr.)	i (Amp.)		t_1		t_2		t
				MV	Degrees.	MV	Degrees.	
Without stirring.								
16	350	6·0	F	8940	954·4°	8983	958·2°	956 3°
		8·3	M	8960	956·1	9016	961·0	958·6
		0·0	F	8973	957·3	9000	959·6	958·5
		8·0	M	8970	957·0	9014	960·9	959·0
		6·5	F	8926	953·2	9006	960·2	956·7
		9·0	M	8970	957·0	9014	960·9	959·0
17	500	5·0	F	8968	956·8	9001	959·7	958·3
		8·0	M	8963	956·4	9018	961·2	958·8
		5·5	F	8942	954·6	8995	959·2	956·9
		8·0	M	8950	955·3	9011	960·6	958·0
With stirring.								
18	500	5·0	F	8931	953·6	8947	955·0	954·3
20	380	6·0	F	8950	955.3	8967	956·7	956·0
		10·7	M	8931	953 6	9004	960·0	956·8
		8·0	F	8890	950·0	8943	954·6	952·3

obtained by the wire method. We assume therefore 955° as the mean melting point of silver in air, but at the same time we wish to emphasize the fact that the point is not well defined and, especially with the wire method, may suffer considerable variations with the nature of the surrounding atmosphere.

The "spitting" was also frequently observed through the mica covers. It took place between 933° and 940°, in the mean at about 936°, and was much more violent when the melted metal had been previously stirred.

The attempt to saturate the melted silver by allowing oxygen to bubble through it and thereby to reach a definite point of solidification for this condition led to no satisfactory result. The thermo-element showed considerable temperature oscillations throughout the solidification, but the mean, as was to be expected, lay much below the other determinations. Four observations gave the temperatures 939°, 938°, 942° and 938° — approximately the same temperature at which the absorbed oxygen is given off as noted above. Curve D (fig. 4) shows one of the time curves taken under these conditions, though it is by no means characteristic of all. In one case for instance with the temperature falling gradually, oxygen began to be given off at about 940°, whereupon the temperature began to rise, and reached 963° in the next five minutes, a violent spitting going on throughout the interval. At the latter temperature the metal became suddenly rigid and closed the porcelain tube through which the oxygen was entering.

(2) *In a Reducing Atmosphere.*—Higher results and better defined are obtained by preventing the access of oxygen. We sought to accomplish this first by melting the silver under a layer of common salt and afterward in a plumbago crucible over which a second crucible was inverted as a cover.

The time curves in both cases, for both melting and solidifying points, showed well defined horizontal segments, as may be seen from fig. 4, curves B (under NaCl) and C (in graphite).

Table XVIII contains a series of such observations from which 961·5° is obtained as the melting or solidifying tempera-

TABLE XVIII.

Melting Point of Silver in Absence of Oxygen.

Date.	G. (gr.)	*i.* (Amp.)		*t.*	
				MV.	Degrees.
In Porcelain Crucible under NaCl.					
Nov. 23	400	5·3	F	9023	961·7°
		10·7	M	9026	961·9
		6·7	F	9023	961·7
		11·3	M	9026	961·9
In Graphite Crucible.					
Dec. 8	352	6·7	F	9018	961·2
		9·5	M	9019	961·3
		6·0	F	9018	961·2
		9·3	M	9018	961·2

ture of pure silver. No spitting was observed under these conditions.

For the wire method neither of these courses is open for making determinations in the absence of oxygen. The bare junction cannot be placed in melted salt on account of its conductivity nor exposed to the reducing atmosphere of a plumbago crucible without danger of affecting the thermo-element.

Copper.—The melting point of copper was not determined by the wire method on account of the oxidation of the metal. In the crucible, the material used was pure copper in 100 gr. blocks from the *Haddernheim Kupferwerk* and determinations were made in both oxidizing and reducing atmospheres.

TABLE XIX.

Melting Point of Copper.

Date.	G. (gr.)	*i.* (Amp.)		*t.*	
				MV.	Degrees.
In Oxidizing Atmosphere.					
Nov. 7	900	——	F	10216	1065·1°
29	330	7·5	F	10213	1064·8
		11·0	M	10215	1065·0
		7·5	F	10213	1064·8
		10·8	M	10214	1064·9
Dec. 5	350	10·3	M	10219	1065·3
		8·0	F	10210	1064·6
		10·5	M	10216	1065·1
6	350	7·5	F	10211	1064·7
		10·3	M	10220	1065·4
		7·0	F	10211	1064·7
		9·9	M	10219	1065·3
Mar. 19	370	6·8	F	10213	1064·8
		10·3	M	10213	1064·8
		6·8	F	10211	1064·7
		10·3	M	10211	1064·7
21	370	6·5	F	10212	1064·7
		8·5	M	10214	1064·9
		8·5	M	10216	1065·1
23	370	8·2	M	10216	1065·1
		8·2	M	10219	1065·3
In Reducing Atmosphere.					
Dec. 7	355	7·5	F	10442	1084·3
		10·2	M	10440	1084·2
		7·2	F	10440	1084·2
		10·4	M	10437	1083·9

(1) *In an Oxidizing Atmosphere.*—Copper differs distinctly from silver in that when melted in an open porcelain crucible it possesses perfectly definite and coincident melting and solid-

ifying points. This seems to indicate that the copper under these conditions becomes saturated with a definite quantity of oxygen or rather with a copper oxide.

To assure ourselves regarding the constancy of this point we have made a great many observations of it without being able to notice any essential variation.

It was also quite indifferent whether the copper was fresh or had been several times used for the same purpose before.

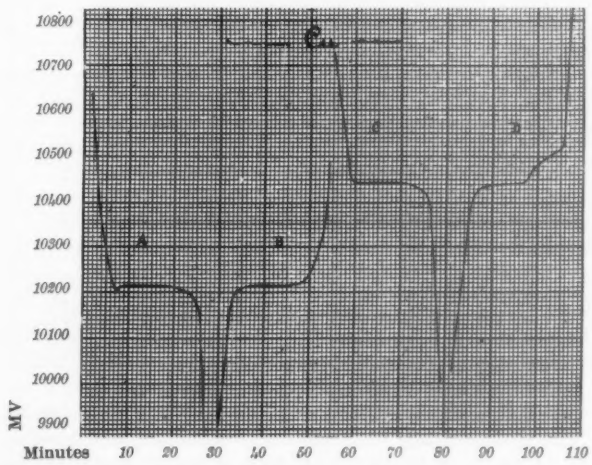
After many determinations with a particular mass of metal it seemed to melt with increasing difficulty, a phenomenon which points to a decrease in its conductivity for heat, but should receive rather more investigation. Table XIX contains the results of the observations, giving 1064·9° as the melting point of copper in air.

(2) *In a Reducing Atmosphere.*—If the same metal which has been repeatedly melted in air be heated in a plumbago crucible it gradually reduces and the melting point rises, ultimately reaching 1084° after the metal has remained for a long time in a molten condition and become thoroughly reduced.

Melting points obtained between 1065° and 1084° where the reduction is still incomplete give poorly defined curves.

At the close of Table XIX some observations with the pure metal are given. Fig. 5 shows time curves for observations in

5.



porcelain crucibles (curves A and B) as well as in graphite (curves C and D).

If the melted copper contained oxygen, the unglazed porcelain tube which served to protect the thermo-element was

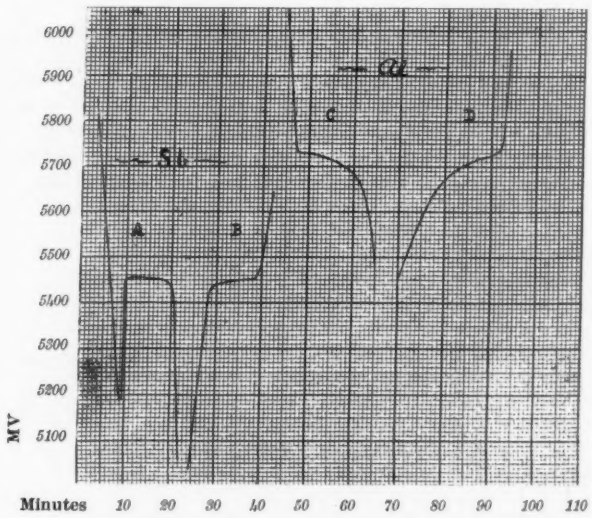
always colored black while pure copper had no noticeable effect upon it.

Antimony.—The antimony with which our determinations were made, as well as the following metals, were obtained from C. A. F. Kahlbaum, chemist, in Berlin; with the exception of aluminium they may be regarded as pure.

For melting the antimony only graphite crucibles were employed, and even then a slight superficial oxidation was observed after cooling. Reducing gases were not introduced on account of the thermo-elements.

In solidifying, the temperature first sank far below (as much as 20°) the melting point, to which it then rose suddenly (see fig. 6, curve A). The time curves are otherwise normal. The mean value for the melting temperature was 630·6°.

6.



Aluminium.—Aluminium was melted in both porcelain and graphite crucibles. As has been noticed already by former observers, this metal shows no sharply defined melting point. Its time curves are similar in form to those obtained from silver in air. We give the melting point as 657·3°—the mean of the results obtained in the porcelain crucible. The melting temperatures observed in graphite were slightly lower to be sure, but the difference is more probably due to the smaller quantity of metal used.

The melting point of aluminium is not a sufficiently well-defined point for use in calibrating thermometrical apparatus;

should a temperature in this region be desired, the melting point of antimony is preferable.

Zinc.—The melting temperature of zinc can also be determined in an open porcelain crucible provided the same zinc be not too often used—with too much oxide present, the curves were less well-defined. In graphite the form of the time curve and the temperature are the same as in porcelain. The mean melting temperature may be given as 419·0°.

Lead.—The only noticeable feature in the determination of the melting point of lead is its small melting or "latent" heat, which makes some attention to the regulation of the oven temperature necessary. The mean melting point is 326·9°.

Cadmium.—The melting heat of cadmium is much greater and sharp curves are obtained with little trouble. Its mean value is 321·7°.

In Table XX are contained the determinations of the melting and freezing temperature of antimony, aluminium, zinc, lead and cadmium.

Tables XXI and XXII contain examples of the time curves as they were observed, the numbers representing the thermo-electric force in microvolts as observed from minute to minute.

Alloys.—In conclusion certain alloys remain to be mentioned whose melting points we investigated by the wire method only.

The metals were in thin strips cut from sheets of perhaps 0·2 to 0·3^{mm} thickness, prepared especially for the purpose by the Frankfurt *Scheideanstalt.*

As the investigation could only be undertaken in an oxidizing atmosphere, alloys of silver and copper gave no definite results whatever. The silver melts and separates out of the partly oxidized copper, leaving it to interrupt the circuit by breaking at a considerably higher temperature.

The two alloys 95Ag5Au and 90Ag10Au were especially prepared to ascertain whether the addition of a small quantity of gold would prevent the action of oxygen on the melting point of silver. The observed results seem to negative this assumption.

The temperature scale for the highest melting points is based upon exterpolation from the curve of the normal element T_2 (Table XVI).

6. *Measurement with Thermo-elements.*

Some ten years ago when the first platinum—platin-rhodium thermo-elements were obtained from the firm of Heräus for the measurement of high temperatures, both the platinum and the rhodium were so imperfectly purified chemically that the duplication of an element with approximately the same thermo-

TABLE XX.

Date.	G (gr.)	i (Amp.)		t MV	t Degrees	
			Antimony.			
Dec. 14	260	0·0	F	5453	630·8°	In graphite.
		8·5	M	5449	630·4	
		5·0	F	5452	630·7	
		7·5	M	5448	630·3	
			Aluminium.			
Dec. 4	180	0·0	F	5729	657·7°	In porcelain.
		8·5	M	5723	657·1	
		4·5	F	5727	657·5	
		7·5	M	5723	657·1	
		4·3	F	5725	657·3	
Dec. 9	110	0·0	F	5717	656·6	In graphite.
		8·0	M	5707	655·6	
		5·0	F	5718	656·6	
		7·5	M	5705	655·4	
			Zinc.			
Dec. 2	389	4·2	F	3377	419·2°	In porcelain.
		7·9	M	3375	419·0	
		0·0	F	3376	419·1	
		7·0	M	3374	418·9	
Mar. 30	293	0·0	F	3376	419·1	In graphite.
		7·3	M	3375	419·0	
		0·0	F	3376	419·1	
		7·3	M	3373	418·8	
			Lead.			
Dec. 15	500	0·0	F	2507	326·9°	In porcelain.
		7·0	M	2508	327·0	
		0·0	F	2505	326·7	
		6·0	M	2505	326·7	
Mar. 26	493	0·0	F	2505	326·7	In graphite.
		5·8	M	2508	327·0	
		4·2	M	2510	327·2	
		0·0	F	2510	327·2	
		4·2	M	2510	327·2	
			Cadmium.			
Dec. 2	430	0·0	F	2461	321·9°	In porcelain.
		6·0	M	2460	321·8	
		0·0	F	2458	321·6	
		6·7	M	2459	321·7	
		0·0	F	2457	321·4	
		6·5	M	2459	321·7	
Mar. 27	430	0·0	F	2459	321·7	In graphite.
		4·3	M	2458	321·6	
		0·0	F	2461	321·9	
		4·3	M	2460	321·8	

electric force was impossible. The platinum was the first to be successfully purified, then, sometime after, the rhodium. Thermo-elements from different meltings now show variations of only 1 per cent, when formerly 10 per cent, and more was observed. The wires are also much more homogeneous now than formerly.

TABLE XXI.

"Time Curves" (MV).

Min.	Ag under NaCl	Ag under NaCl	Ag in Graphite	Ag in Graphite	Cu in Porcelain	Cu in Porcelain	Cu in Graphite	Cu in Graphite
1	9423	8513	9439	8766	10590	10003	10680	10081
2	9330	8599	9354	8861	10475	10106	10609	10179
3	9247	8684	9255	8956	10370	10183	10530	10268
4	9130	8775	9156	9016	10310	10201	10455	10353
5	9039	8857	9056	9018	10240	10207	10444	10409
6	9024	8937	9018	9018	10210	10210	10442	10426
7	9024	9017	9017	9019	10210	10210	10442	10431
8	9023	9023	9018	9019	10212	10211	10442	10433
9	9022	9024	9018	9019	10214	10213	10442	10436
10	9022	9024	9018	9019	10213	10213	10442	10437
11	9022	9025	9017	9022	10213	10213	10443	10438
12	9022	9026	9017	9033	10214	10213	10443	10439
13	9021	9026	9016	9043	10213	10214	10443	10440
14	9021	9026	9013	9055	10213	10214	10442	10440
15	9020	9026	9006	9064	10212	10215	10442	10441
16	9018	9026	8976	9074	10212	10215	10441	10444
17	9014	9027	8763	9121	10211	10216	10439	10456
18	9007	9028		9290	10210	10219	10437	10472
19	8990	9027			10210	10227	10433	10484
20	8800	9029			10208	10245	10427	10491
21	8600	9029			10203	10268	10410	10497
22		9029			10200	10300	10342	10503
23		9031			10193	10340	10195	10509
24		9034			10177	10460	10070	10516
25		9037			10097		9968	10564
26		9050			9900			10720
27		9069			9740			
28		9232						
29		9350						
30								

Since the platinum wire at temperatures above 1000° is considerably less stable than the platin-rhodium, much would be contributed in the direction of the durability of the elements if the platinum could be replaced by some related metal or alloy of greater stability.

Up to the present, however, no satisfactory substitute has been found. The alloys of platinium with iridium and ruthenium, in part also with palladium, differ little in their thermo-electric properties from platin-rhodium.

Pure palladium does possess a higher thermo-electric force when combined with platin-rhodium than platinum, but can-

TABLE XXII.

"Time Curves" (MV).

Min.	Sb in Graphite	Sb in Graphite	Zn in Porcelain	Zn in Porcelain	Pb in Porcelain	Pb in Porcelain	Cd in Graphite	Cd in Graphite
1	6216	5223	3551	3265	2718	2309	2852	2392
2	6080	5294	3500	3316	2671	2353	2809	2425
3	5960	5360	3449	3344	2621	2401	2767	2442
4	5840	5408	3400	3351	2574	2450	2726	2449
5	5720	5430	3376	3355	2529	2496	2685	2454
6	5600	5437	3376	3359	2506	2503	2646	2456
7	5495	5441	3376	3362	2506	2504	2607	2457
8	5390	5443	3376	3365	2505	2505	2570	2458
9	5280	5445	3376	3368	2505	2505	2533	2459
10	5190	5445	3376	3369	2505	2505	2496	2459
11	5450	5446	3376	3369	2505	2506	2462	2460
12	5454	5447	3375	3370	2504	2507	2460	2460
13	5454	5448	3375	3372	2503	2510	2459	2460
14	5453	5448	3375	3372	2502	2514	2459	2461
15	5454	5448	3375	3373	2501	2521	2459	2461
16	5452	5449	3375	3373	2497	2529	2459	2463
17	5452	5449	3374	3374	2488	2572	2459	2469
18	5451	5450	3373	3374	2473	2676	2459	2485
19	5451	5456	3374	3374	2444		2459	2499
20	5448	5468	3373	3374	2365		2458	2525
21	5438	5488	3373	3375			2458	
22	5310	5512	3372	3375			2457	
23	5060	5555	3370	3376			2456	
24		5655	3366	3389			2454	
25			3357	3404			2452	
26			3342	3433			2449	
27			3300				2422	
28							2367	
29								
30								

not be considered in this connection, for it is even less stable at high temperatures than platinum.

Thermo-elements made from different alloys of platin-rhodium such as were formerly used by Holborn and Wien* for temperatures above 1000° are also unsuited for general use on account of their low sensitiveness.

* L. Holborn and W. Wien, loc. cit.

TABLE XXIII.

Melting Points of Alloys.

Alloy.	t		Mean.	Alloy.	t		Mean.
	MV	Degrees.			MV	Degrees.	
95 Ag, 5 Au	8989	958·7		95 Au, 5 Pt	10805	1115·0	
	8990	958·8			10799	1114·5	
	8980	957·9	958·5		10826	1116·8	
					10827	1116·8	1116·0
90 Ag, 10 Au	9067	965.5					
	9070	965·8		90 Au, 10 Pt	11551	1177·2	
	9080	966 7			11522	1174·9	
	9060	964·9			11533	1175·7	
	9070	965·8	965·7		11495	1173·6	
					11578	1179·7	
40 Ag, 60 Au	9753	1025·3			11482	1171·5	
	9756	1025·5			11599	1181·2	1176·3
	9730	1023·3					
	9760	1025·9		85 Au, 15 Pt	12285	1237·4	
	9757	1025·6	1025·1		12282	1237·1	
					12273	1236·4	
95 Au, 5 Pt	10821	1116·4			12317	1240·0	1237·7

Thermo-elements were first intended only for the measurement of temperatures from red heat upwards; afterwards it became evident that lower temperatures could be measured by this means as well. There is no advantage gained by going below 250°, however, as the errors due to the decrease in the sensitiveness at the lower temperatures begin to be more noticeable.

The accuracy of thermo-electric measurements in the earlier investigation of Holborn and Wien (loc. cit.) was stated to be 5°. The present results carry it further. It could fairly be said that, for temperatures up to 1150°, the present error would be about 1°; that is to say, for any distribution of temperature between the junctions, the temperature of the hot junction is defined by the thermo-electric force to within ±1°.

This does not in the least mean however, that with constant conditions considerably more accurate relative measurements cannot be made. The determinations of the melting points of the metals contain many examples of this.

The chief reason for this progress lies in the facilities for electric heating whereby the whole investigation of high temperatures gains in accuracy and simplicity.

For the thermo-elements the change is especially important since the electric oven allows a definite temperature distribution to be exactly reproduced at any time, whence it becomes

possible even with inhomogeneous wires to carry out accurate temperature measurements by always working under the same conditions. It should be borne in mind however that this accuracy is only relative and that the same thermo-elements with a different temperature distribution between the junctions may show considerable variations.

To obtain the limits of absolute accuracy the fall in temperature along the wire must be varied as much as possible.

In the investigation here presented this was accomplished in two ways, either by measuring the temperature at a given point with two elements having a common hot junction and so arranged that the fall in temperature along the wire from the hot to the cold junctions could be varied; or secondly, by using as many different points of an element as possible successively, as junctions, and comparing them in a very short oven under exactly similar conditions of temperature distribution.

For example, by the first method the temperature near the end of a long electrically heated tube would be measured with two elements joined at their hot junctions, and the one passing out at the end near by, while the other extended through the middle of the tube which is hotter than near the ends, and out at the far end. It is clear that the distribution of temperature from hot to cold junction along the wires of the two elements would be very different and could be varied at will by simply moving the common junction to and fro.

Any lack of homogeneity in the wires would then become apparent at once in differences between the readings of the two elements.

We rather preferred the second method, the small melting-point oven (fig. 3) being well adapted to the purpose.

The wires of the elements are best simply bound together with a short platinum wire when it is desired to use several points provisionally as hot junctions. It has however no influence upon the thermo-electric force if the wire be cut in different places and afterward joined in the oxy-hydrogen flame.

Thick lumps along the wires are in the way to be sure, but with a little practice a junction can be made which can hardly be detected.

Thermo-elements as they are now prepared in a diameter of $0{\cdot}6^{mm}$ are very homogeneous and over a length of several meters show no differences which could affect the temperature measurement 1°. Thin wires reduced from the above by drawing are often less uniform. Two wires, for example, which had been drawn down to $0{\cdot}25^{mm}$ showed about double this variation, nor could this difference between the thin and thick wires be removed by glowing electrically.

Repeated heating to high temperatures may also under certain circumstances render the wires less homogeneous.

Attention has been called to this before, but now that the accuracy of thermo-electric measurements has been so materially increased it becomes necessary to go into the discussion of this matter in considerable detail.

The changes are such as Holborn and Wien observed in platinum and palladium due to the action of combustion gases or hydrogen in the presence of silicium, and which affect the resistance even more than the electromotive force. Even with electric heating where combustion gases should no longer be feared, the walls of an oven which has not been previously heated to a higher temperature than that to be measured, and kept there until burned through and through, develop gases which pass through platinum.

We have called attention to this in the discussion of a platiniridium bulb for the gas thermometer in our earlier communication. The thermo-elements are also affected by exposure to these gases but may usually be protected by the use of porcelain, which does not itself develop such gases and is very impervious to them even in its unglazed form. For temperatures below 1100° still further protection is afforded by glazing of course. Tubes of more refractory material intended for temperatures where porcelain can no longer be used and necessarily imperfectly burned we have found to be porous and when first heated to give off gases themselves at high temperatures which in the presence of silicium affect platinum strongly.

If the wires of a thermo-element which have been exposed in this way be afterward used for temperature measurement, there is often little or no change in the electromotive force from the normal values *so long as the temperature distribution along the wire remains unchanged*, but considerable variations always appear as soon as it is varied.

We made observations for example with such an element C which had been exposed in an imperfectly burned oven, the hot junction being combined with that of a second element A which had not been so exposed. At 550° the following differences (C−A) in microvolts were observed in an electric oven 40^{cm} long in which the common junction of the two elements could be moved from the center toward either end as described elsewhere:

Hot Junction.			I.	II.
At the center (elements symmetrical)			7	7
6^{cm} to the right	2 wires heated	14^{cm}	− 73	+ 3
6^{cm} " left	" "	26^{cm}	+126	+36

In column I the elements were crossed while in II the two wires of each element passed out of the oven at the same end.

Originally the two elements had agreed for all positions to within 5 microvolts.

Further examples could be cited, but we will confine ourselves to two where efforts were made to restore the damaged elements.

The element C′, cut from the same wire as T_2 was in use for a long time for high temperatures in a long oven and there exposed to these gases, after which the following differences were obtained by comparison with the normal elements G and H under *unchanged* conditions of temperature distribution.

t	H−C′	G−C′
200°	+ 5 MV	+5 MV
300	+ 5	+6
400	+ 4	+5
500	−11	+6
600	−13	+7
700	−14	+7
800	−13	+5
900	−12	+7
1000	−13	+7
1100	−10	+8
1200	− 9	+8

When this same element C′ was introduced into the short oven containing melted copper however, where the conditions of temperature distribution were very different, it gave 10,092 MV as the melting temperature while the two normal elements showed 10,212 microvolts.

C′ was then taken out, glowed electrically at full white heat for several hours and again introduced into the copper crucible (with proper porcelain protection of course), when it gave 10,170 under the same conditions as before.

The same measurement was then a third time repeated after 5^{cm} had been cut from both wires at the hot junction—the electromotive force now proved to be 10,220 microvolts. In this condition further measurements were made of the melting points of lead, cadmium and zinc with results 2513, 2460 and 3371 microvolts respectively, all in good agreement with the normal values.

As has been said the glowing was done electrically, as much as 17 amperes being sent through the wires. Connected in series both wires glow with equal intensity at high temperatures, the smaller resistance of the platinum when cold being offset by its larger temperature coefficient.

An element B of the same group was used several times in an oven tube of a new material which was being tried for the first time, up to a temperature of 1600°.

The platinum wire became very brittle in the vicinity of the junction, broke in several places and was melted together in the oxy-hydrogen flame. Afterward when used for measurement at about 1000° in the long oven (unchanged temperature distribution) its reading was some 90 microvolts too low, but for the melting point of copper (different distribution) it gave only 9840 MV, i. e. some 400 MV too low. Sixteen centimeters were at once cut off at the hot junction, first from the platinum and afterward from the platin-rhodium wire, when the melting temperature of copper was given at 10,290 and 10,150 MV respectively. Further shortening did not serve to change these figures and the pieces cut out were again inserted. In this condition the element was glowed as in the previous case for some hours at white heat, when the melting point of copper was read at 10,216 MV—almost exactly the normal value.

The glowing also restores the bright surface to wires (platinum particularly) which have become dull after exposure to these gases.

It is probable that the standard element which represents the earlier temperature scale of Holborn and Wien and which has been used many times for comparisons up to 1600° has undergone similar changes.

Its indications at 500° are now 10°, and at 1000°, 18° too high, while the new determinations of the melting point of gold differ only 8° from the old. This melting point in particular was well determined at that time, the greatest variations from the mean in twenty-five determinations under varied conditions being $\pm$ 4° while the corresponding variations for silver and copper amounted to $\pm$ 10°.

At the lower temperatures no fixed points were then determined so that no further comparison is possible.

We draw the conclusion from this that the temperature scale once established can be maintained with certainty only with the help of fixed temperatures such as the melting points given above. It is further advisable to divide a set of thermo-elements into two groups, one to be used only in porcelain tubes up to say 1200° and the other under other conditions or in higher temperatures.

For the latter, up to the present at least, the same accuracy is neither to be obtained nor expected until observations with the gas thermometer have been made and the technical resources much extended.

Especial attention ought again to be called to the fact that in the measurement of the fall in temperature in an extended space such as is necessary for the calculation of its mean temperature, the utmost care should be taken that the elements be

in perfect order. The best arrangement is always to measure with two elements having a common hot junction and entering the space in question from opposite sides, as has already been described in our former paper.

Furthermore, inasmuch as thermo-elements have come to be employed very generally for technical purposes during the past few years, we take this opportunity to say that it is impossible to give the limits to which the electromotive force can be affected by the breaking of the protecting tube or other accident through which the wires become exposed to combustion gases in the manner above described—the higher the temperature the greater the danger. In case of such an accident the element should at once be tested and restored as elsewhere indicated.

7. *Conclusion.*

By way of conclusion we will bring together the temperatures which we have obtained for the melting points of the metals based upon observations with the gas thermometer and some recent results of other observers employing other methods.

These include the measurements with platinum resistances as carried out by Callendar and by Heycock and Neville* which are also based upon the gas thermometer up to 445°, the boiling point of sulphur, and the higher temperatures exterpolated from a formula of the second degree.

The melting points of gold and silver have also been measured with thermo-elements by Berthelot,† using the wire method and determining the temperature optically from the decrease in density of an air column in an electrically heated, open, porcelain tube.

	Gas Thermometer.	Platinum Resistance.	Optical Method.
Cadmium	321·7°	320·7°	
Lead	326·9	327·7	
Zinc	419·0	419·0	
Antimony	630·6	629·5	
Aluminium	657·	654·5	
Silver, in air	955·	955·	962
Silver, pure	961·5	960·7	——
Gold	1064·0	1061·7	1064
Copper, in air	1064·9	——	
Copper, pure	1084·1	1080·5	

Charlottenburg, May, 1900.

* Most of the figures are taken from Heycock and Neville's paper—loc. cit.; Callendar's values—Phil. Mag. V, xlviii, 519, 1899—differ in several cases 1°.

† D. Berthelot, C. R., cxxvi, p. 473, 1898.

ART. XIX.—*Notes on Certain Schists of the Gold and Diamond Regions of Eastern Minas Geraes, Brazil;* by ORVILLE A. DERBY.

IN a recent communication in this Journal (May, 1899) brief reference was made to certain schists of the region that were supposed to be in some way related to the curious schistose partings in the quartz veins that were more particularly discussed. The single type analyzed presented such an abnormal composition that it appeared desirable to make analyses, kindly executed by Dr. Hussak, of such material, unfortunately scanty, as was at hand as seemed suitable for that purpose. This material includes, in addition to the rock already analyzed by Hillebrand, two of the rocks mentioned in the above cited paper from the diamond mine of São João da Chapada. To these has been added a perfectly sound schist found loose in a topaz washing near Ouro Preto and presumed to represent the decomposed material in which the nests of topaz occur. In addition four analyses by Gorceix of schists of the Ouro Preto region are given from the Annaes da Escola de Minas de Ouro Preto (vols. 1 and 2, 1882, 1883).

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	38·32	37·77	47·83	31·18	54·1	47·4	62·4	36·4
Al_2O_3	28·16	21·37	26·75	20·39	27·3	31·2	22·7	26·1
Fe_2O_3	2·24	28·36	8 51	36·41	7·7	6 7	3 8	23·1
FeO	4 02	----	----	----	----	----	---	----
CaO	0·32	tr.	tr.	tr.	----	----	---	1 3
MgO	12·04	1·05	2·43	0·79	0 8	2 0	1·3	2·1
K_2O	1·11	8·96	10·42	7·18	3·0	4·5	4·2	6·4
Na_2O	0·16	----	----	tr.	3·6	2·7	1·5	1 0
Loss on ignition	8·01	3 89	5·33	3·83	3·8	5·6	3·4	3·9
Other elements	5 69	----	----	----	----	----	---	----
Total	100·07	101·40	101·27	99·78	100 3	100·1	99·3	100·3

I.—Greenish schist with large crystals of cyanite; Serra do Gigante, north of Diamantina; loose block; analyst, Hillebrand (this Journal, May, 1889). "Other elements" include TiO_2 4·93, ZrO_2 0·09, MnO 0·16, (NiCo)O 0·04, P_2O_5 0·47 and traces of SrO, Li_2O, S and F.

II.—Bluish schist found loose in the diamond mine of São João da Chapada but presumed to come from a schistose layer in the lower quartzite (itacolumite); analyst, Hussak. TiO_2 occurs rather abundantly but was not separately determined.

III.—Soft greenish schist found loose in the diamond mine of São João da Chapada but presumed to come from a schistose layer in the upper conglomeritic quartzite; analyst, Hussak. A strong trace of P_2O_5 was noted in the analysis.

IV.—Black schist found loose in a small topaz washing near the Caxambú topaz mine, Ouro Preto, and which possibly represents the original matrix of the topaz occurring in nests in a clay similar to what would be given by the decomposition of this rock; analyst, Hussak.

V.—Unctuous greenish schist from Boa Vista near Ouro Preto; analyst, Gorceix.

VI.—Fibrous schist containing at times crystals of pyrophillite and altered pyrite; Boa Vista near Ouro Preto; analyst, Gorceix.

VII.—Whitish unctuous scaly rock from Boa Vista near Ouro Preto; analyst, Gorceix.

VIII.—Compact violet schist in form of dike in limestone at Ganderela, north of Ouro Preto; analyst, Gorceix.

From macroscopic examination, No. I is evidently a chloritic rock with enormous crystals of cyanite up to 5^{cm} or more in length. The portion insoluble in sulphuric acid (43·41 per cent) calculated, according to Hillebrand's suggestion, as normal cyanite, muscovite, quartz and rutile, gives: cyanite 16·46 per cent, muscovite 8·46 per cent, quartz 13·66 per cent, rutile 4·73 per cent, with a doubtful excess of 0·09 per cent referred to zircon, which could not be found in the heavy residue, while a doubtful trace of zircon oxide was noted in the hydrochloric acid solution indicating that this element probably belongs to a soluble constituent. The soluble portion (56·66 per cent) reduced to 100 agrees very closely with Eaton's analysis of corundophilite from Chester, Mass., the most important differences being an excess of 1·88 per cent SiO_2, 1·13 per cent Al_2O_3, and a deficiency of 4·15 per cent of iron oxides. It is interesting to note that this Chester type of chlorite is also associated with an aluminous mineral, corundum, and that the somewhat similar type with the same association from the Culsagee mine, N. C., carries Mn, Ni and Co like the soluble portion of the Brazilian rock. Another element, monazite, revealed in minute quantities by washing, is probably indicated by the phosphoric acid of the analysis.

In the paper above cited an argument for the eruptive origin of this and other schists of the region was drawn from the occurrence of antigenetic monazite, which was considered as an original element that had passed unchanged through the process of metamorphism. This argument must now be withdrawn since, as will be shown in the following paper, evidence has recently come to hand that monazite may be formed by secondary processes; one of the proofs being furnished by the rock in question, which shows rutile included in monazite in the same manner as in the associated chlorite and cyanite. The probable origin of this rock will be discussed farther on.

No. II, as shown by microscopic examination, is essentially a micaceous rock heavily charged with a fine dust of hematite, which is easily removed by hydrochloric acid, leaving a considerable amount of a poorly characterized titanium mineral, rutile or anatase, which should give a small percentage of titanium not determined in the analysis. The alumina is nearly 8 per cent short of the amount required by the potash for normal muscovite and this deficiency is too great to be supplied by iron. Calculated on the basis of the Hallgarten sericite, however, the deficiency of alumina is reduced to a reasonable limit, and there can be no doubt that the rock is composed of 70 per cent more or less of sericitic mica with perhaps 2–3 per cent of chlorite and a small percentage of rutile, or anatase, and probably also of quartz. Washings réveal the merest trace of autigenetic monazite, which, in a measure, confirms the identification of this rock with the decomposition product (micaceous clay rich in iron oxide and with rutile) of a sheared dike in the vicinity.

No. III is in appearance a purely micaceous rock with no evidence, even in the heavy residue, of more than the merest trace of free quartz and hematite. It is so soft as to go easily to a slime in water and is apparently considerably decomposed, but this appearance is not confirmed by the high percentage of potash, which for normal muscovite requires 7·25 per cent more alumina than is given by the analysis. The rock probably contains over 80 per cent of an iron-bearing sericite with, perhaps, 7 per cent, more or less, of chlorite and a small percentage of quartz and earthy iron oxide. Washings reveal a small amount of microscopic tourmaline, of which some grains appear to be secondarily enlarged, and worn zircons of a size and abundance that seem extraordinary in a rock of such fine grain and of so purely argillaceous character. A trace of phosphoric acid was noted in the analysis and a very decided reaction was obtained from the heavy residue, so that it is certain that monazite is also present although in its rolled state it cannot be distinguished from the zircon.

No. IV is very similar to No. II in appearance and composition with a somewhat less deficiency of alumina for normal muscovite and a considerably greater percentage of free iron oxide. A trace of phosphoric acid indicates the presence of a phosphate, of which, however, no trace could be detected in the heavy residue, so that it probably is neither apatite nor monazite. The heavy residue shows a relatively small amount of autigenetic rutile and tourmaline and in this respect agrees with that of the decomposition clays of the immediate vicinity with nests of topaz, which, so far as can be made out, must have

resulted from the decay of a rock very similar to the one analyzed.

Nos. V, VI and VII were analyzed by Prof. Gorceix for the express purpose of determining whether the denomination "chloritic" or "talcose," ordinarily applied to the predominant schists of the region, was applicable or not. They may, therefore, be presumed to be the most typical unctuous schists that could be found in a sufficiently sound state to be analyzed. All three show a considerable amount of soda, which in No. V is in excess of the potash, so that the micaceous element cannot be a normal muscovite. Alumina is somewhat in excess of what is required to satisfy the alkalies as normal muscovite and it was noted that macroscopic pyrophillite occurs in the bed from which No. VI was taken, so that it is probable that the excess of alumina may, in all three rocks, represent a small percentage of this mineral, or of cyanite, which is also very frequent throughout the region. Free iron oxide was noted in No. VI in the form of altered pyrite and it is probable that No. V also carries a small amount in the same state, or in that of hematite. All three show a considerable excess of silica, doubtless in the form of quartz, and the small percentage of magnesia probably represents a slight admixture of chlorite. Nothing is known of the heavy residues of these rocks or of the details of their mode of occurrence.

No. VIII has almost exactly the amount of silica and alumina required to satisfy the alkalies and magnesia as normal muscovite and chlorite, leaving an excess of about 8 per cent of silica for quartz. As in Nos. II and IV the iron is probably, for the most part, in the state of hematite.

All of these rocks show a low to extremely low percentage of silica and a high to extremely high one of alumina, while all without exception are poor in lime and, except No. I, in magnesia as well. On the other hand, all but No. 1 show tolerably high percentages of alkalies.

From these analyses no certain conclusion as to the original mineralogical composition and mode of origin of these rocks can be drawn. On the somewhat risky assumption that the present chemical composition of metamorphic rocks is, as regards non-volatile constituents, essentially identical with the original composition, no satisfactory comparison with known types can be made for the majority of these rocks. Nos. V and VII agree fairly well in composition with some of the trachytic and phonolitic tuffs cited in Zirkel's Petrographie, vol. iii, pp. 675 and 680. If, as is unusually done with such rocks, they be considered as metamorphosed arkose, the material must have been derived from a syenitic (or porphyritic) type rich in soda rather than from an ordinary granite or gneiss.

Neither of these hypotheses, however, will apply to Nos. III and VI, which, if original clastics, must have been almost purely micaceous sediments with, in the case of the latter, a slight admixture of kaolin. No. III is certainly clastic as proved by the heavy residue and it is presumed to represent a thin, shaly parting in a conglomeritic quartzite derived from an underlying micaceous quartzite and for this such an hypothesis is not improbable. Nos. II, VI and VIII also, if clastic, must likewise have been essentially micaceous but heavily charged with limonite. It is, however, improbable that in five representatives, taken by chance, of original argillaceous sediments, all should prove to be essentially micaceous and none essentially kaolinitic, and the hypothesis may be suggested that in the case of marine clays a gain in alkalies may possibly take place from soluble salts imprisoned from the sea water. No. I, regarded as a clastic, must have been a singular mixture of kaolinitic and magnesian clays.

On the other hand, the hypothesis of eruptive origin for any of these rocks, with the possible exception of Nos. V and VII, involves that of unknown and improbable types, or that of an important loss of lime and magnesia with a consequent concentration of alumina, iron and alkalies. In the paper above cited arguments for the possible eruptive origin of Nos. I and II were deduced from the presence of antigenetic monazite, the lack of recognizable allothigenetic elements and, in the case of No. II, from a presumed connection with a decomposed sheared dike in the immediate vicinity as well as of traces of original structure. The first argument has proved fallacious but the others still hold good and the second one is equally applicable to No. IV, while No. VIII (very similar in composition to Nos. II and IV) was taken to be a dike by Gorceix in his field examination, though it is probable that if he had known its composition a more detailed examination of this point would have been made.

In the same paper reference was made to a peculiar rock from near the fall of the river Dattas which presents many analogies with No. II but with more decided eruptive characteristics. Both of these rocks were supposed to be allied to No. I, and when that on analysis proved to be chloritic rather than sericitic, as was at first supposed, it was assumed that this might also be the case with the two rocks in question. A qualitative* analysis of the Dattas rock, however, shows that

* As the rock is heavily charged with tourmaline, which is evidently an introduced element, it was considerated that its original composition had been so changed that the work of a quantitative analysis would not be compensated by the results.

like No. II, it is very poor in lime and magnesia and that it is composed essentially of a sericitic mica heavily charged with hematite dust. The two rocks are therefore closely similar, chemically as well as mineralogically, and it can safely be affirmed that the principal differences revealed by a complete analysis would be only such as correspond to the presence of the characteristic elements of tourmaline and to a greater abundance of titanium and probably also of iron oxide, both in the free state. These two rocks also agree in presenting on a polished section transverse to the plane of shearing, appearances of original structure that in the Dattas rock are perfectly well-defined but somewhat indistinct in the other. This appearance is that of the mottled aspect of a rock composed of an intimate mixture of white and colored elements, as, for example, a diabase or a basalt. In the Dattas rock the minute white areas are perfectly defined rectangles like those of the feldspar of the rocks mentioned, while in that from São João da Chapada (No. II) they appear to have lost their original sharpness of outline through shearing. Under the microscope, these rectangular areas of the Dattas rock are seen to be composed of a sericitic aggregate free from the iron and titanium dust with which the rest of the section is thickly sprinkled. On dissolving out the iron, the distinction between the white and colored areas disappears and the whole slide presents a sericitic aggregate sprinkled with a dirty white dust of titanium oxide, rutile or anatase, which before had been concealed by the iron. The appearance is that of a basaltic rock composed of a well crystallized white element (plagioclase or melilite) in a groundmass containing bisilicates (pyroxène?) or in a basic glass rich in iron and titanium oxides, which on alteration has settled in the place of the original minerals, or glass, but without invading the areas of the white element. In addition to this secondary iron (hematite) and titanium dust, the rock also contains these two elements as primary constituents in the form of crystals, often of considerable size, of magnetite and of minute octahedrons of an altered titanium mineral that was most probably perofskite.

The peculiar structure and characteristic primary accessories of this rock are strongly suggestive of an original basaltic character and, in view of the perofskite, most probably a melilite-basalt. On this hypothesis, however, the original rock must have been rich in lime and magnesia and its present chemical and mineralogical composition can best be explained by the hypothesis that before metamorphism it had been decomposed and leached *in situ*, the resulting residual clays and oxides retaining their original positions without mingling. A confirmation of this hypothesis is apparently to be found in

the peculiar manner in which the rock has been invaded by tourmaline. This mineral besides lining the shear and fracture planes with beautiful and symmetrical microscopic rosettes of radiating needles, also appears in the body of the rock, where, however, it is confined to the white areas, the needles being sharply cut off by the rectangular limits of the original crystals wholly or in part substituted by tourmaline. This invasion evidently took place after the decomposition and shearing but perhaps during the process of the recrystallization of the rock.

There is nothing intrinsically improbable in the hypothesis that some metamorphic schists may result from the alteration of rocks, both massive and clastic, that had been decomposed and leached *in situ*, and thus many of the anomalies of composition that this group presents may be satisfactorily explained. This hypothesis is involved in that presented by Vogt and Van Hise of the derivation of micaceous iron schists of Norway and of the Lake Superior region from original carbonates, and in another place evidence pointing in the same direction will be presented in relation to the extensive itabirite beds associated with the schists here discussed. If, as seems probable, the itabirites are derived from decomposed and leached carbonates, the process must have taken place on a gigantic scale in the region in question and the associated silicate rocks, whether massive or clastic, must have been affected to a greater or less extent.

The hypothesis of leaching cannot, however, be applied satisfactorily to the rock No. I, which, if an original basic eruptive of any of the ordinary types, must have lost heavily in lime and iron while magnesia was retained. This, however, would be contrary to what is supposed to have taken place in the other rocks here discussed and to what is generally observed in the modern cases of decomposition and leaching. Moreover the presence of monazite in this rock is, so far as present experience goes, incompatible with such types. It seems more probable that in this case the composition has remained comparatively unchanged and that the original rock must have been one of low silica, iron and lime, but of high alumina and magnesia associated with a considerable variety of rare elements. No type of rock with these characteristics has as yet been clearly defined, but that such may exist, either independently or as local phases or segregations in other types, is suggested by the occurrence of corundum and aluminous silicates in association with olivine rocks in North Carolina and Georgia, and that of alumina-magnesia silicates such as cordierite, prismatine and sapphirine as segregation (?) masses in the granulite of Saxony and the mica schist of Fiskernäs, Greenland. If, as may be presumed from the scanty information at hand,

these latter minerals, with their associates, form independent rock masses, a possible prototype for such schists as No. I can be imagined. The question still remains of the mode of origin of such a prototype if it exists, but the occurrence of corundum in olivine rocks shows that the association of alumina and magnesia in ultra basic eruptives is not an impossibility.

The probable occurrence in this rock of a soluble compound of zirconia is also suggestive of a possible prototype in the nepheline- or augite-syenite groups, in which such compounds have thus far proved to be most frequent and in which rocks with corundum indicating an excess of alumina have lately been recognized. Thus far, however, no member of this group at all approaching in composition the Serra de Gigante rock appears to have been described. That rocks of this group may have existed in the district and have contributed to the metamorphic schist series, is perhaps indicated by the perofskite- and, possibly, melilite-bearing schists from the neighborhood of Dattas.

As to how far the above analyses are typical of the phyllites of the series in question can only be conjectured. These, which as regards thickness are evidently more important than the quartz, iron-mica and calc-schists with which they are associated, present almost universally an aspect that has led to their being generally denominated as chloritic or talcose, that is to say they are predominantly of micaceous texture and of a character that suggests magnesian minerals. True chloritic and talcose as well as amphibolitic schists undoubtedly occur in the series, but it is almost certain that they are subordinate to sericitic schists, agreeing more or less perfectly in character with Nos. II to VIII of the above analyses. So far as can be judged from a superficial examination of material which for the most part is profoundly decomposed, the more quartzose types represented by Nos. V. to VII are the most abundant and characteristic, and these, from their composition and intimate association with the quartz schists, may be presumed to be, for the most part, of clastic origin. If so, however, the original clays must have been sufficiently rich in alkalies to form a sericitic mica as the predominant element of their metamorphosed state. Judging from the above analyses and from the almost universally micaceous character of the phyllites of the region, the proportion of alkalies must have been very uniformly above 5 per cent.

It is interesting to compare with the proportion of alkalies above deduced for these phyllites that given in the extensive list of analyses of ceramic materials in vols. 16 and 18 of the annual reports of the U. S. Geological Survey. Out of 550

analyses in which the alkalies were determined, only 67 (12 per cent) have over 5 per cent of potash and soda; 99 (18 per cent) over 4 per cent, and 177 (30 per cent) over 3 per cent. In the 87 that are given as slate, shale or shale-clay, the proportion having over 5 per cent is the same (11=12 per cent), but below this figure it rises rapidly, the numbers being 22 (25 per cent) with more than 4 per cent of alkalies and 62 (72 per cent) with more than 3 per cent.

In the low proportions of alkalies the difference above noted may reasonably be attributed to the greater amount of water in the earthy types, but this explanation will not apply in the comparison of the shales with the Minas schists, which, considered as original clastics (as a large, and probably the greater, part undoubtedly were), appear to have been uniformly richer in alkalies than the normal clay deposits of more recent times. If this conclusion is correct, these ancient argillaceous deposits must either have been composed quite uniformly of comparatively sound felspathic or micaceous material rather than of kaolin, or in some way the original proportion of alkalies must have been increased. The hypothesis above given that some of these schists are of eruptive origin will in part explain the predominance of micaceous rocks in the region, but, for the present at least, there are no good reasons for supposing that these constitute more than a small fraction of the whole. The case of No. III shows that a high proportion of alkalies is not necessarily indicative of eruptive origin and a number of other highly micaceous rocks have been washed with the same result of a residue with well-characterized allothigenetic elements.

An excess of alumina over that required by the alkalies to form mica, and which goes to form aluminous silicates, seems also to be a common feature of the schists of the region, as cyanite is a very common mineral both in the rock outcrops and in the loose material of the surface, as well as an element, often predominant, of the concentrates of the gold and diamond placers. In general, however, it appears to come from the more quartzose rather than from the more micaceous members of the series and in these cases it may be presumed to represent kaolin in original clastic sediments. Other aluminous silicates that resist decay so as to appear in the washings, as staurolite, are not at all prominent. From some of the above analyses it may be suspected that pyrophyllite will prove to be a common and widespread element, but from its liability to be confounded with mica it can only be detected in perfectly sound rocks, that are rare in the region. As above indicated, this excess of alumina may be attributed to the normal presence of kaolin in original clastics, or to the leaching of original eruptives.

A high proportion of iron oxide, more frequently in the state of hematite than of magnetite, is also a very common feature in the micaceous as well as in the quartzose and calcareous rocks of the region. In the latter case and in that of the actinolitic and a part at least of the quartzose iron schists (itabirites), it may be presumed to come from original carbonates. In other cases it may be attributed to iron sand in clastic deposits, to original elements either oxides or silicates, in eruptives, or to a leaching of limonite into rocks of any character. It is almost invariably accompanied by a certain proportion, often high, of titanium oxide as rutile (more rarely as anatase) which after quartz and the iron oxides is the most abundant and constant mineral of the gold and diamond concentrates. This, whether in clastics or eruptives, is probably indicative of original ilmenite. Chrome mica occasionally appears in the quartzites of the region and in one case (a pebble from the conglomerate of the Cavallo Morto diamond mine near Diamantina) this could be traced very satisfactorily to grains, evidently clastic, of chromic iron contained in the same rock and which probably indicate that a peridotitic rock has contributed to the original sandy deposit.

ART. XX.—*Notes on Monazite;* by ORVILLE A. DERBY.

Solubility in acids.—In order to test the relative solubility of the mineral in different acids a sample of monazite sand from Prado, Bahia, was freed from all admixture by careful picking and after grinding was submitted in parcels of about half a gram each to the action of 100 centigrams of the ordinary laboratory acids each diluted with one part of water. After standing for 68 hours without heating, phosphoric acid was determined in each solution as follows: in nitric acid solution, 2·51 per cent; in hydrochloric acid, 1·62 per cent; in sulphuric acid, 1·39 per cent.

Magnetism.—In cleaning up residues with the electro-magnet it has been found that monazite can be quite successfully separated from its usual associate, zircon, and that when monazite and xenotime occur together the latter can, by a proper graduation of the points, be almost entirely drawn away from the former. In one case in which the instrument had been used with an opening between the points of about a centimeter, for the separation of pyroxene of the acmite type which may be presumed to carry about 30 per cent of iron oxide, a mixed sample of monazite and zircon was very neatly and quickly separated without reducing the distance between the points, both minerals being equally free from iron staining or inclusions.

Microchemical reactions —A single granule of the mineral, no matter how minute, can be rapidly and securely identified by moistening it with sulphuric acid on a slip of glass and burning off the acid over a spirit lamp. The characteristic crystallization of cerium in double ball-shaped clusters of radiating needles or minute cucumber seed-shaped isolated crystals, can usually be detected after this operation in the ring of evaporated material about the granule, but better after adding a drop of water and allowing it to evaporate in a desiccator. Another drop of water with a slight admixture of ammonium molybdate solution added to the same preparation gives on evaporation a very satisfactory reaction for phosphoric acid. The reagents are best applied by means of a small loop on the end of a very fine platinum wire and an excess should be avoided, especially with the acid, as too large a drop is liable to run in a very annoying manner in the heating. The same reactions are given by the recently discovered cerium-aluminium phosphate, florencite of Hussak and Prior, but this can be distinguished by its form and cleavage when these are recognizable. The microcrystalline forms of cerium and yttrium

sulphates are so similar that a confusion with xenotime is also to be guarded against. It has recently been found also that soluble silicates containing zirconium give very similar forms in the sulphuric acid test, but these are readily distinguishable by the absence of phosphoric acid. Confirmatory tests with oxalic acid have not proved uniformly successful and can usually be dispensed with. The Florence test by crystallizations in a blowpipe bead requires from a half a dozen to a dozen grains of the usual size and is more successful with the salt of phosphorus than with the borax bead in which the presence of phosphoric acid appears to exercise a disturbing influence, although with patience the crystals characteristic of cerium can be obtained.

When, as is usually the case, the grains are transparent, the micro-spectroscope will also usually give a very satisfactory test on a single grain of the usual size, by means of the absorbtion band of didymium. This can also be obtained by either reflected or transmitted light with an ordinary hand, or rainband, spectroscope, when a number of grains can be brought close together in balsam on a microscopic slide.

Natural etching.—The grains of monazite from decomposed pegmatites or muscovite-granites are frequently etched, though not to the point of completely obliterating their original form and faces, but the phenomenon has rarely been observed in the decomposition-products of other types of rocks. In a miner's residue from the Cavallo Morto (Dead Horse) diamond mine near Diamantina the extraordinarily abundant monazite grains (the mineral is lacking or rare in the residues of most of the mines of the district) are extremely fresh in appearance, presenting a strong contrast with the well-worn aspect of the associated zircons, and under the microscope this difference is seen to be due to the profound natural etching of the grains. The deposit is reported by a competent observer to be a decomposed metamorphosed conglomerate like others of the vicinity, and in this case the monazite grains should be equally worn with those of zircon. On the contrary, however, they have been completely rejuvenated in appearance and amongst thousands passed in review under the microscope, none showing what could be positively identified as original or worn faces were seen except when, as in the case of the latter, these had been protected by the secondary enlargements described below. In similar deposits in the neighborhood in which the cement of the ancient conglomerate was evidently highly argillaceous, a similar etching of the included quartz grains is almost universal and is often very beautiful.

Secondary enlargement.—In the above-mentioned residue from the Cavello Morto mine, many grains show a darker cen-

tral portion surrounded by perfectly clear material having the same optical orientation, but, like all the grains of the residue, without distinct crystalline form. The appearance is that of a rounded and worn grain with secondary enlargements principally in the form of clusters of spindle-shaped prolongations of the two poles of an original ovate grain. So far as can be made out from the color and from rather unsatisfactory optical tests, the clear outer shell is of monazite material, and this conclusion is apparently confirmed by microchemical tests, since grains in which the central nucleus appeared to be entirely protected from the action of the acid gave very satisfactorily the cerium and phosphoric acid reactions. As there was a possibility that the enlargement might be the newly discovered cerium-aluminium phosphate, florencite, which, when the form is not distinct, is readily confounded with monazite, a small quantity of the residue was tested by wet analysis for alumina, but with a negative result. It thus seems tolerably certain that in the clastic rock from which the residue comes there had been a new formation of monazite such as has been shown for tourmaline and several other minerals in similar rocks. The main objection to this conclusion is that monazite, as an autigenetic element, is thus far only positively known in rocks of eruptive or presumably eruptive origin, but this objection is weakened by evidence presented below indicative of a possible secondary origin.

Inclusions.—The monazite thus far extracted from granites, gneisses and porphyries, and that found in secondary deposits derived from these rocks, is free from inclusions, and in these cases the mineral, together with the associated accessories (zircon, magnetite or ilmenite, or both, and occasionally the phosphates xenotime and apatite), has evidently been one of the first to crystalize out of an eruptive magma. Quite recently, however, evidence has come to hand, that it may also be formed in other ways and probably by secondary processes. In addition to the secondary enlargements above noticed, which were evidently formed in a metamorphosed clastic rock, the following cases have been noted.

From the residues of diamond washings at São João da Chapada and Sopa near Diamantina, and from a gold washing at Bandeirinha in the same neighborhood, the monazite crystals of the peculiar prismatic habit described in a recent number of this Journal (vol. vii, p. 353) are frequently found heavily charged with scales of hematite and more rarely with minute needles and grains of rutile. This type of monazite has been traced home to some peculiar schists of the region that are presumed (in part on the evidence of the perfectly fresh condition of the monazite crystals), to be of eruptive

origin. In the schists from Sopa and São João da Chapada, which are almost purely sericitic, the monazite is free from inclusions, but in the chlorite-cyanite schist from the Serra do Gigante the monazite, like the accompanying chlorite and cyanite, is full of minute grains of rutile and no essential difference in the character and mode of occurrence of the inclusions in the three minerals can be detected. Whatever may have been the original nature of this rock, the silicate elements and the rutile are clearly secondary, and there is no escaping the conclusion that the monazite must be so also.

In a small gold-working called Ogó* a few hundred meters away from the great diamond mine of São João da Chapada, monazite of the ordinary type occurs with rutile in the peculiar partings, composed almost exclusively of bright green muscovite, of a quartz vein in diabase. The crystals are here of the type known as turnerite and both they and the associated muscovite and rutile closely resemble those of the microscopic residue obtained from a specimen of the Binnenthal gneiss faced on one side with the well known macroscopic crystals of that locality. In the case of the Brazilian crystals, however, rutile and muscovite are included in them in such a way as to show contemporaneous crystallization. The rock is a peculiar one and in its present condition may be suspected to be a secondary product, but this cannot be proven. A decomposed massive quartz-muscovite rock from the same mine, which in appearance is of the same nature as the partings except for being finer-grained and more quartzose, did not give monazite. The exposure is unsatisfactory and as in the field examination the greenish rock was taken to be a chloritic alteration phase of the diabase, no special attention was given to it beyond taking a specimen that quite unexpectedly proved of great interest. The quartz vein with its peculiar micaceous accompaniment suggests a comparison with the quartz-kaolin (pegmatitic?) veins of the same vicinity and may be suspected to be a special type of granitic apophyses.

If the possibility of a secondary formation of monazite be admitted, a more plausible explanation than that given in the paper above cited (that of an intimate interlamination of eruptive and clastic material, can be given for the micaceous partings and selvages of the Sopa quartz veins that afford perfectly fresh monazite mixed with well-worn zircons.

* Ogó, which is apparently a term of African origin, is the name given to the fine heavy concentrate of microscopic minerals obtained in panning for gold and diamonds, when the predominant color is yellow. It may consist of monazite, xenotime or rutile, or a mixture of all three, the first generally predominating. In panning the miner, seeing the formation of a heavy yellow concentrate, is often deceived and on cleaning up exclaims in disgust "the gold turned to ogó".

Occurrence in basic rocks.—Up to a very recent period the rule seemed to be very firmly established that it was useless to look for monazite as an antigenetic element in any but highly acid rocks. In the scores of rocks examined, both sound and decomposed, it had been found to be almost universal in the muscovite granites, or their porphyritic and gneissic equivalents; frequent in the biotite granites, but lacking in the amphibole-granites and all other more basic rocks that had been examined. The monazite-bearing schists above mentioned from Sopa, São João da Chapada and Serra do Gigante, however, indicate that this rule is not general, though as the type of mineral that they present is peculiar and perhaps of secondary origin, it may be that it only requires to be somewhat modified rather than set entirely aside. The Sopa schist (that one free from zircon) have not been analyzed, but it is evidently composed almost exclusively of sericite and there is no difficulty in considering it as a modified porphyry. That of São João da Chapada, though basic in the low silica (37·77 per cent) and high iron (28·36 per cent, for the complete analysis see No. II of the preceding paper) contents, may, as I attempted to show in the paper above cited, be plausibly considered as a basic phase of a mixed dike of essentially granitic character. No such hypothesis is, however, possible with the Serra do Gigante schist with its 38·32 per cent of silica, 28·16 per cent of alumina and 12·04 per cent of magnesia. As already stated under the head of inclusions, all the elements of this schist are apparently secondary and it might therefore be considered as a metamorphosed sedimentary clay. The high percentage of magnesia is, however, anomalous for such a clay and in the preceding paper in which this rock is more fully discussed the hypothesis of the decomposition and leaching, prior to metamorphism, of an original eruptive rock is suggested. Even so, however, it seems necessary to imagine a type of eruptives that has not yet been clearly recognized though there are indications of its possible existence.

Art. XXI.—*The Spectra of Hydrogen and the Spectrum of Aqueous Vapor;* by John Trowbridge.

It is customary to consider that there are two spectra characteristic of hydrogen—a four-line spectrum, so-called, and another consisting of many lines widely distributed through the spectrum, known as the white spectrum. The four-line spectrum appears when a condenser discharge is employed with what is called dry hydrogen: it is also readily produced in steam and water vapor. From the fact that a condenser discharge seems necessary to excite it in dry hydrogen, it is supposed to indicate a higher temperature than the white spectrum.

The four-line spectrum is found in the atmosphere of the sun; and is a characteristic spectrum of certain types of stars. There are also other lines attributed to hydrogen in the stars which are supposed to indicate conditions of pressure and temperature which perhaps can be imitated and studied in laboratories.

I propose to show, in this paper, that conclusions in regard to temperature and pressure of hydrogen in celestial bodies, deduced from observations on hydrogen enclosed in glass vessels, are untrustworthy; and that electrical dissociation must be considered as a most important element in determining the characteristics of a gaseous spectrum—more important indeed than the question of pressure and apparent temperature.

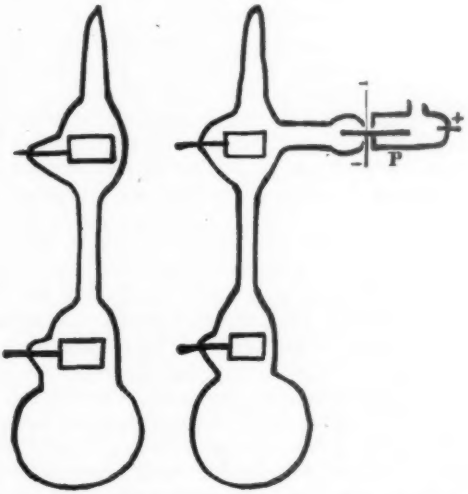
I shall give my reasons for believing that the four-line spectrum of hydrogen in the atmosphere of the sun is an evidence of aqueous vapor in that atmosphere and therefore is an evidence of the existence of oxygen in the sun. The conviction is forced upon me that the term dry hydrogen is a misnomer, when the gas is subjected in glass vessels to condenser discharges or to sufficiently powerful steady currents of electricity.

The bibliography of the subject of the spectra of hydrogen is so extensive that I must, with due regard to the limits of this article, refer the reader to the reports of the committee of the British Association, and to the recognized bibliographical authorities on this subject, and I do this because I feel that in my experiments I have exceeded the experimental limits of previous investigators; for I have been enabled to employ more powerful electrical discharges than have been hitherto possible. My work, therefore, does not trench in this respect upon that of previous investigators.

The source of the electrical energy I employed was twenty thousand storage cells of the Planté type. The direct current from these cells through a liquid resistance was used to produce the white spectrum; and a glass condenser consisting of 300 (three hundred) plates of glass—each plate having a coated surface of 16x20 inches—with a total capacity of about 1·8 microfarads—was charged by the cells to produce the four-line spectrum.

I had great difficulty at first in obtaining tubes which would stand such powerful discharges. I began my work with end-on tubes which were closed by plates of quartz luted on by silicate of soda. The electrodes were hollow cylinders of aluminum connected to thick pieces of platinum wires. These

1



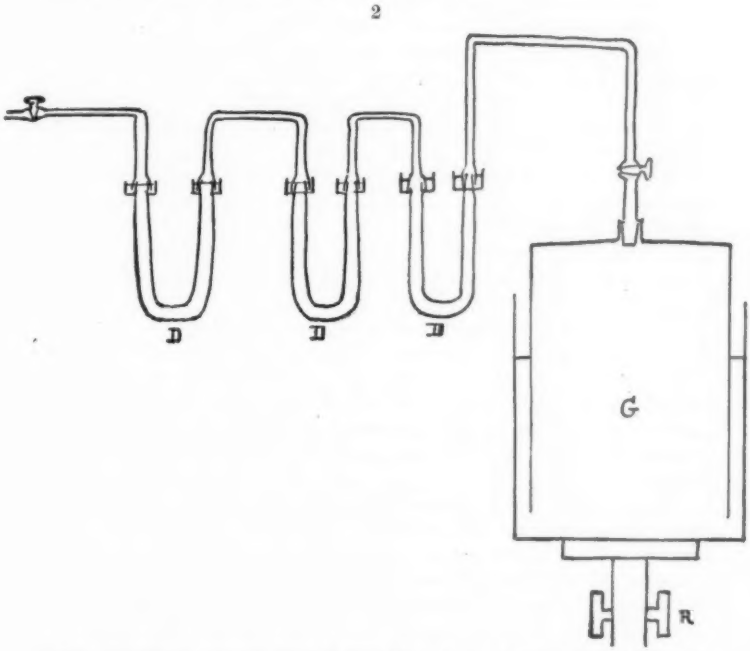
wires passed through the walls of the glass tubes, and were immersed in large vessels of distilled mercury. After considerable experience tubes were constructed which would resist the disruptive and heating effects of the discharges. This form of tube, however, was abandoned for another form, shown in fig. 1. The chief peculiarity of this form of tube is an X-ray bulb in place of the end covered with the quartz plate. The reason of the adoption of this form of tube is this: it was necessary to heat the entire tube to a high temperature for a long period during the process of exhaustion, to drive out the air and aqueous vapor before it was filled with hydrogen, and this heating was impossible with a luted-on end.

Moreover the thin glass of the bulb did not appreciably absorb the ultra-violet rays until the wave length 1800 was reached, and this absorption did not affect my conclusions since my work was confined to the portions of the spectrum studied by astrophysicists. The diameter of the narrowest portion of the tubes was about 1^{cm}. I employed still another form of tube, shown also in fig. 1. At one side of this tube there was an adjunct consisting of a palladium tube P on the outside of the spectrum tube joined hermetically to a platinum wire inserted in the walls of the tube. A glass vessel filled with dilute sulphuric acid slipped over the palladium tube. At one end of this glass vessel was inserted a platinum wire. The palladium wire was made the cathode and the platinum wire the anode of a battery. In this way hydrogen is liberated on the surface of the palladium tube, is then occluded and can be made to pass into the spectrum tube.*

The tubes which were not provided with palladium tubes were filled with hydrogen or nitrogen, through a series of tubes filled with caustic potash, and through a number of tubes filled with phosphoric pentoxide provided with partitions of glass wool. After many attempts I adopted the following arrangement of these tubes, which proved satisfactory. In the first place I found it necessary to discard all gums or other adhesive material and to use ground-glass joints and mercury seals for these joints, having satisfied myself that all other forms of connections consume time and are worthless. The tubes were mounted on a board and after the joints had been adjusted the final adjustment with the gas holder could be readily and safely accomplished by means of a rack and pinion which raised or lowered by slow degrees the gas holder fig. 2. This drying arrangement could be exhausted to a high degree and would hold the rarified gas as long as desired. The method of filling the tubes was as follows: the spectrum tube was exhausted to about $\cdot 1^{mm}$, having been repeatedly filled with hydrogen. This operation was continued until the hydrogen spectrum appeared. Finally the tube was exhausted to the X-ray stage by long heating and by employing a strong condenser discharge. Then the dried gas was admitted until a pressure of about $\cdot 1^{mm}$ remained in the tube. The vessels with palladium tubes were carefully exhausted to the X-ray stage (and beyond, a spark preferring to jump six inches in air to passing through the tube). When these tubes with the palladium adjunct were connected to the terminals of the battery a slight heating was sufficient to start a discharge and to cause the occluded hydrogen to appear in the spectrum tube.

* A device due to Dr. William Rollins, Boston.

The operation of heating the spectrum tubes is highly important; moreover the discharge from a condenser should be employed in the process of exhaustion and the operation should be continued for several hours. In this subject of the exhaustion of tubes I am much indebted to suggestions of Dr. William Rollins and Mr. Heinze of Boston, who have had long experience in the preparation of X-ray tubes. This experience I believe is indispensable to one who essays to investigate the spectra of gases in glass vessels.



The vacuum pump was a modification of Rapp's pump. It was automatic. There was but one valve and the number of ground-glass joints with mercury seals was reduced to a minimum. The hydrogen was produced by the electrolysis of phosphoric acid and doubly distilled water. The gasholder contained many liters of the gas. The nitrogen was prepared by passing air through ammonia water, then through heated copper gauze, then through tubes of caustic potash; and finally through tubes of phosphoric pentoxide.

The spectroscope consisted of a Rowland grating with a ruled surface five inches by two inches, and a radius of curva-

ture of sixty inches. The dispersion was small on account of the small number of lines to the inch; but it had the advantage of exhibiting the salient features of the spectra on one plate, with a dispersion of the order used by astrophysicists; and thus enabled comparisons to be readily made. The distance between the great H lines in the second spectra was approximately 2^{mm}. The camera was on an arm pivoted at half the distance between the slit and the grating. This arrangement was adopted for compactness. The grating and camera were enclosed in a light-tight box and a lever enabled me to expose the plate when this box was closed.

Various liquid resistances were employed to regulate the strength of the electric current. I finally used distilled water, which was kept running through glass tubes. Since my object was not to measure the current, but rather to keep it within safe limits, I did not find it necessary to employ cadmium terminals in a solution of iodide of cadmium. The direct battery current gave me the white type of hydrogen spectrum, while the second type was given by the powerful condenser discharges. A revolving drum provided with suitable metallic strips enabled me to safely charge and discharge the condensers through the spectrum tubes.

In working with powerful condenser discharges I found that I obtained essentially the same spectrum whether the tube was filled with hydrogen, rarified air or nitrogen, notwithstanding the great care taken in heating the tubes and drying the gases; this characteristic spectrum was that of water vapor—containing lines of hydrogen and of oxygen—with traces of nitrogen lines.

The employment, therefore, of a condenser discharge in glass tubes drives off aqueous vapor from the glass walls, even if extraordinary care is taken to expel such vapor in the process of exhausting such tubes. My experiments entirely confirm Professor Crookes' statement on this point. Glass seems to be of a permeable nature, and in the process of manufacture is doubtless filled with gases which reveal themselves when disruptive electrical discharges are employed. It does not seem possible that dry hydrogen can exist as such in a tube when it is subjected to a condenser discharge; and I therefore believe that the spectrum of hydrogen called the four-line spectrum is an evidence of the presence of aqueous vapor, for it can be produced with the greatest ease when we are certain that this vapor is present. This spectrum, to my mind, is an evidence of the presence of oxygen in the sun's atmosphere.

The true spectrum of hydrogen seems to be the white spectrum. This is developed by a steady current which should

not exceed a certain strength; for a powerful one drives off also rarified air from the walls of the tubes and there is a process of occlusion set up if large metallic terminals are employed. Such large terminals are necessary if very strong currents are used. With aluminum electrodes under the action of strong currents, spectra of the combinations of nitrogen with oxygen and hydrogen are produced in tubes presumably filled with pure dry hydrogen. When the tubes have been subjected to very strong currents it seems impossible to refill them with pure hydrogen. In one case I filled a tube with pure dry nitrogen and passed a current through it sufficiently powerful to melt down one of the aluminum hollow cylinders which formed an electrode. The aluminum surface was filled with cavities as if gases had bubbled from the interior. When this tube was filled with dry hydrogen it gave again spectra of compounds of nitrogen and no trace of the hydrogen spectrum. A powerful condenser discharge, however, produced the aqueous vapor spectrum. Hydrogen, thus, is extremely elusive when subjected to electrical dissociation in the presence of other gases in glass vessels with metallic electrodes, and indeed, a steady battery current can be employed at a certain stage of exhaustion to occlude hydrogen to such a degree that the vacuum is apparently raised and no discharge can be forced through the tube until it is subjected to external heat. This occlusion or destructive electrical dissociation is very much in evidence when the terminals of a battery of ten or twenty thousand storage cells are connected to an X-ray tube through a resistance of several megohms. If this tube is properly exhausted, that is by repeated heating and by the use of electrical discharges, no current can be forced through it unless the tube is repeatedly flashed with a powerful Bunsen burner. Suddenly, however, under the action of the heat a blue cloud rises in the tube. The cathode beam appears, the anticathode grows intensely hot and the exterior resistance must be quickly increased to save the tube. The pressure has apparently been greatly reduced; but the experiment of Dr. William Rollins with two connecting X-ray tubes, one of which is heated and the other not, the heated one carrying a current and the other resisting an eight-inch spark, shows that this is not the case and that we have to deal with electrical dissociation and not with change of pressure. Let us follow this experiment further. Presently the blue cloud in the tube grows smaller, the cathode beam disappears and the cloud slowly sinks into the positive electrode. At that moment the X-rays flash out with great brilliancy; but in a few seconds the light in the tube is totally extinguished, and a further heating from an external source is necessary before the phenomena can be repeated. It can be

repeated as often as desired, although the apparent resistance of the tube undoubtedly is raised by a more or less permanent occlusion of what I believe is water vapor. This experiment strongly recalls the familiar one of the glowing of platinum under a stream of non-ignited hydrogen. The electrical dissociation of the aqueous vapor evidently produces an intense heat at the anticathode and the X-rays are emitted during this dissociation.

If we suppose that there are material bodies circulating about the sun and charged negatively—the sun being charged positively—we might conceive of a similar action of a difference of potential on rarified aqueous vapor, which would be competent to produce a corona.

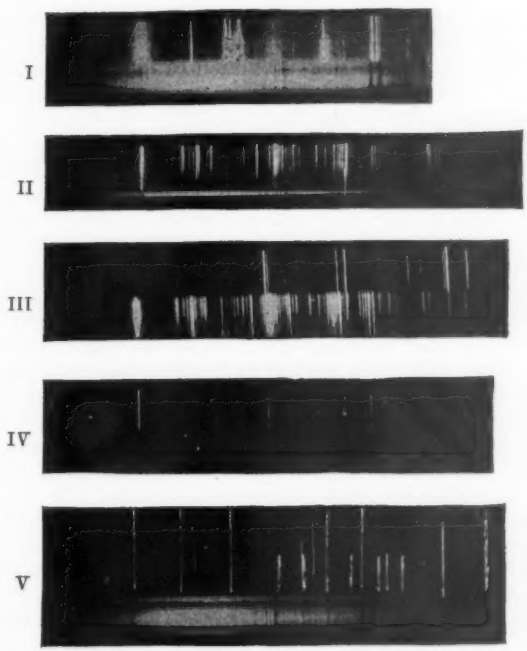
The white spectrum of hydrogen produced by hydrogen coming from palladium is in its main feature similar to that obtained from electrolytic hydrogen which is passed through the drying apparatus I adopted.

There are some bands, however, which need examination to determine whether they arise from impurities conveyed into the tube from the pump. The palladium tube apparently supplies hydrogen more or less continuously to the tube to repair the loss from the process of electrical dissociation, and is therefore more reliable than the form of tube which is filled with hydrogen through drying apparatus which necessarily cannot be subjected to heat, and through which rarified air is conveyed with hydrogen into the spectrum tube.

The study of the effect of powerful electrical discharges on hydrogen led me to endeavor to find the lines in the star ζ Puppis discovered by Professor E. C. Pickering: since their approximate wave lengths satisfy a modification of Balmer's formula, Professor Pickering attributes them to hydrogen. The wave lengths of these new lines are comprised in the spectral region extending from about 4200 to 3700. I have plotted them as short lines contiguous to the normal solar spectrum in fig. 3, No. V. The long lines correspond approximately to the most intense lines or bands in the spectrum of hydrogen produced in the tube provided with the palladium adjunct. The hydrogen spectrum when regarded as a whole on the scale of small dispersion I have employed, seems to be made up of lines spaced according to a certain order, very much as if two sets of lines spaced according to a certain arrangement should be superposed on each other; the fingers of one hand shifted over those of the other. The hydrogen lines are more or less intensified bands or dark accumulation of lines almost obscured by the spectra produced by the compound of nitrogen and aqueous vapor if a very strong battery current is employed in a tube provided with aluminum electrodes. It is possible that certain

hydrogen bands may be narrowed and rendered lines in a spectrum of small dispersion such as astrophysicists are compelled to employ, by an electrical dissociation of water vapor in the presence of an excess of oxygen, and that these new lines may thus be evidence of the presence of aqueous vapor in the stars of this new type. To test this theory I filled a tube with

3



oxygen, and submitted it to a powerful condenser discharge. The resulting spectrum was of the general type obtained by these strong discharges in hydrogen, rarified air and nitrogen. It is shown in fig. 3, No. IV. If we compare this spectrum with I, in which the broad bands represent hydrogen lines in hydrogen at atmospheric pressure; with II, the spectrum of rarified air; also with the lower one in III, the spectrum obtained in pure nitrogen, we see that the main hydrogen lines are narrower and certain hydrogen lines are so faint as to be hardly visible even on the negative.

The general character of the spectral lines of hydrogen in respect to breadth and intensity seems not to depend so much

upon mere pressure and apparent temperature (temperature deduced from calculations of electrical energy in electrical discharges) as upon electrical dissociation of gases: of aqueous vapor, for instance in the presence of an excess or a small supply of oxygen. I believe, therefore, that any conclusion in regard to temperature and pressure of hydrogen in the stars deduced from laboratory experiments with electrical discharges in glass vessels are misleading, since we have mainly to do with phenomena of electrical dissociation and not of pressure and apparent temperature—that is temperature which can be measured by calorimetric methods or which can be calculated from the electrical dimensions of the circuit which is employed.

It would seem, therefore, that the study of electrical dissociation is necessary for the solution of problems relating to the conditions of gases in the atmosphere of the sun and in that of the stars. This seems to be a logical necessity, since the electromagnetic theory is far reaching and sensible heat is only one of the manifestations of electrical energy.

My conclusions are as follows:—

1. When a condenser discharge is sent through a rarified gas which is confined in a glass vessel, the gas can no longer be considered in the dry state: for aqueous vapor is liberated from the glass. When a sufficiently powerful condenser discharge is employed, dry hydrogen, dry nitrogen and rarified air give substantially the same characteristic spectrum. When a very powerful steady battery current is used to excite the tubes filled with these gases—various compounds of nitrogen and oxygen—nitrogen and hydrogen are formed if aluminum electrodes are employed.

2. The four-line spectrum of hydrogen in the solar atmosphere is an evidence of aqueous vapor, and therefore of oxygen in the sun.

3. Conclusions in regard to the temperature of the stars exhibiting hydrogen spectra are misleading, if based upon conditions of pressure and temperature in glass vessels; for conditions of electrical dissociation of aqueous vapor, for instance, the presence of an excess or lack of supply of oxygen, are the controling ones rather than conditions of the mere pressure of the gases.

4. X-ray phenomena produced by a steady battery current strongly suggest an electrical theory of the origin of the sun's corona.

Jefferson Physical Laboratory, Harvard University.

Art. XXII.—*On a New Effect produced by Stationary Sound-Waves;* by Bergen Davis.

In the course of an investigation upon the action of sound-waves, under certain conditions, I have found that if a small cylinder, which is closed at one end, is placed in a stationary sound-wave, it will not only arrange itself perpendicularly to the motion of the wave, but will actually *move* across the wave in a direction perpendicular to the stream-lines. The force producing this motion is of considerable magnitude and it acts normally to the closed end of the cylinder, causing it to move in the direction of the closed end, i. e., the closed end is driven toward the wall of the pipe.

In investigating this effect I have used an organ pipe for the production of the stationary wave, its length being 70^{cm}, and the breadth and thickness $6{\cdot}35^{cm}$ by 5^{cm}, respectively. The pipe when giving its first overtone made 358 vibrations per second. From the dimensions above given, it follows that a node will exist at 22^{cm} from the mouth-piece, and also at the stopped end. One wall of the pipe was made of glass. A thin rubber diaphragm was placed across the pipe near the node next to the mouth-piece, thus converting the remainder of the pipe into a closed chamber. The air in this chamber was in this way kept free from any currents that might arise from blowing the pipe. A diaphragm of this kind at the node, does not alter the intensity of the sound appreciably. The pipe, when blown very hard furnished a very strong overtone.

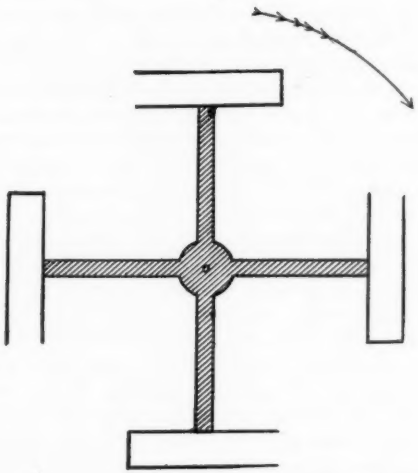
The small cylinders were made from "No. 00 gelatine capsules" such as are used for medical purposes. The hemispherical ends of these capsules were removed, and flat paper discs substituted for them at one end, the other end being left open. Four of these cylinders were arranged as shown in fig. 1. This system of cylinders was supported by a small glass pivot, which was mounted on the point of a fine needle. The needle was attached to a glass rod which was destined to carry the system into different regions of that part of the pipe located behind the protecting diaphragm.

The strength of the air blast was measured by a mercurial manometer, which was used to obtain the same force of blast throughout a series of experiments. The pipe was placed vertically with the stopped end downward, and the glass rod bearing the system of cylinders was introduced from below through an airtight opening. It could be moved up and down in the pipe, and the system of cylinders placed in any desired position in the stationary wave. The plane of the system of

cylinders was perpendicular to the direction of the stream-lines. A scale was placed along the pipe in such a position that the zero was at the stopped end, and the node was at division 48 and the middle of the loop at division 24.

A stroboscopic disc was used to determine the rate of revolution.

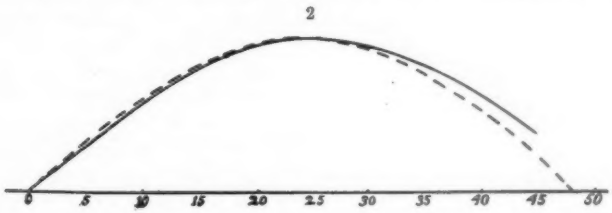
1



Matters being thus arranged, it was found that the system of cylinders when placed in different parts of the closed portion of the pipe rotated with different velocities. A maximum was obtained at the middle of the loop, viz: at 24 and a minimum at either of the nodes, viz: at 0 and 48. The mean results of a set of experiments are given in the table below.

Position of cylinders in pipe.	Rates of revolution per second.
2	·77
7	3·53
12	6·43
17	7·70
21	8·74
24	9·00
26	8·80
29	8·47
32	8·12
37	7·00
42	4·69
47	·92

The above table is plotted in a curve shown in fig. 2. The abscissæ are distances along the pipe and the ordinates are rates of revolution per second. The full line is the observed curve; the broken line is a sine curve. The agreement of the two curves is sufficiently close to suggest that the rate of revolution at any point in the stationary wave is proportional to the velocity of the vibrating air particles at that point. The



curve rises slightly above the sine curve near the dividing membrane, viz: from 30 to 48.

So far as I am aware a rotation of this kind has not before been observed.

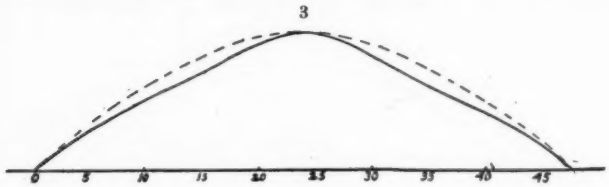
The force involved in the above reaction was measured with the aid of a double cylinder supported by a fine wire, which went up through the wall of the organ pipe inside of a glass tube, 20^{cm} long. This double cylinder was carried at the end of a torsion arm and each cylinder was ·757^{cm} in diameter and 3·1^{cm} in length. The area of cross-section of each cylinder was ·45 $^{sq.\ cm.}$. The pipe was placed in a horizontal position during the torsion experiments.

The amount of torsion necessary to bring the cylinders back to their original position was read on a graduated circle at the top of the glass tube.

The mean results of a number of experiments are given below.

Position of cylinders in pipe.	Torsion.
2	12°
7	·72°
12	190°
17	355°
21	480°
23	555°
27	490°
32	315°
37	165°
41	72°
45	14°

The force exerted upon the cylinders increases very rapidly from the nodes to the middle of the loop. The table is plotted in a curve shown in fig. 3. The ordinates are the *square roots* of the plate readings. The curve corresponds not badly to a sine curve. Experiments with cylinders of the same length but of smaller diameters gave almost an identical curve.



Experiments made in various gases.—The body of the pipe between the diaphragm and the stopped end forms a closed chamber and into this chamber various gases were introduced. The pipe was still set into action by an ordinary *air* blast. The sound wave within the pipe was transmitted through two media, air and the gas, the diaphragm forming the division between them. The force of the air blast was kept constant throughout the experiments. The torsional measurements were made only at the middle of the loop. Although the number of vibrations executed by this composite mass of gas changed very much, the position of the node at the diaphragm was but slightly altered.

Several readings were taken in air, before and after each experiment with the gases. A fresh supply of gas was introduced into the pipe before each reading. The mean results of these experiments in different gases are given in the annexed table. The readings in air, as well as its density are taken as unity.

	Torsion deflections.	Density of gas.
Air	1·	1·
CO_2	1·47	1·52
Illuminating gas	·77	·75
Hydrogen	·064	·069

As will be seen, the force exerted is proportional to the density of the gas.

The rates of revolution of the system of cylinders mentioned above were also taken in the different gases and the mean result of several experiments are given below, the rate of revolution in air being taken as unity.

Air.	Illum. gas.	CO_2.	Hydrogen.
1·	1·	1·04	·59

The rate may be considered as approximately a constant for all the gases, although the force producing this rotation varies with the density of the gas. This can be explained by the circumstance that the resistance to motion is also proportional to the density. The deviation from this result in the case of hydrogen is explained by the fact that the friction on the supporting pivot was not an inconsiderable quantity compared to the total resistance experienced by the cylinders, and this factor is proportionately larger in the case of hydrogen.

Prof. Hallock first suggested to me the explanation of the effect described in this paper.* He pointed out that Daniel Bernoulli has shown that a gas in motion is virtually less dense than the same gas at rest. The air in the capsule cylinder is at rest, while that on the outside of it is in motion. The energy exerted is due to the difference in density on the two sides of the closed end of the cylinder.

An inspection of the curve in fig. 3 shows that the force is approximately proportional to the square of the velocity of the vibrating air.

I have applied this effect to the problem of determining the amplitude of the vibrating air particles in the middle of the loop of the stationary wave. It is evident from the formula given below, that if the force per unit of area on the closed end of the cylinder is obtained experimentally, the change of density may be found, and the amplitude of vibration calculated from it.

Prof. R. S. Woodward has kindly assisted me in applying the proper principles of hydrodynamics to the problem. The relation between the velocity, pressure and density of a moving fluid may be expressed by Bernoulli's equation, since, for this case the average state of the fluid only is under consideration.

$$\int \frac{dp}{\rho} = \mathrm{R} - \tfrac{1}{2} u^2$$

R is the potential due to external forces, and is negligible in this case; hence

$$\int \frac{dp}{\rho} = -\tfrac{1}{2} u^2$$

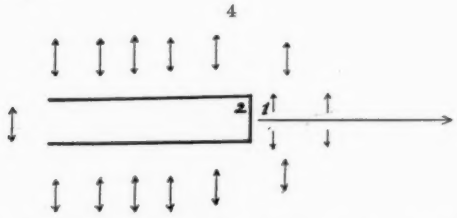
The adiabatic gas relation gives, $p = c\rho^{\mathrm{r}}$, where c is the gas constant.

* This effect is somewhat similar in nature to the acoustic attractions and repulsions of Guthrie and the rotating mill of Dvořak that is, they all depend on the change in density arising from motions of a fluid. The effect herein described is of a different order of magnitude than that of the rotating resonators B D.

By substitution and integration I obtain,

$$\frac{1}{n}\frac{p_2}{\rho_2}\left[1-\left(1-\frac{p_2-p_1}{p_2}\right)^n\right]=\tfrac{1}{2}(u_1^2-u_2^2),$$

where $n=\dfrac{\gamma-1}{\gamma}$.



The cylinder is in the moving air as shown in fig. 4; u_1 is the velocity of the vibrating air outside of the cylinder, u_2 is the vilocity inside the cylinder near the closed end. P_2 and p_1 are the pressures on the two sides of the closed end of the cylinder. If the air in the cylinder next to the closed end is at rest, then u_2 becomes zero.

By expansion and reduction, the above equation becomes;

$$u_1^2=2\frac{p_2-p_1}{\rho^2}$$

p_2-p_1 is the quantity measured on the torsion balance. The absolute value of the pressure as determined from the experiments gave a force of 21 dynes on an area of one sq.^{cm}. This gives a linear velocity to the vibrating air of 187^{cm} per second. The amplitude so obtained is 2·61^{mm}. This value for the amplitude is somewhat less than a corresponding value obtained by means of the sound-wave anemometer recently devised by myself, an account of which will be shortly published.

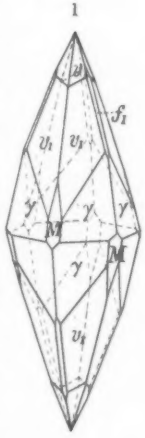
Physical Laboratory, Columbia University,
June 1st, 1900.

Art. XXIII.—*On some Interesting Developments of Calcite Crystals;* by S. L. Penfield and W. E. Ford.

1. Calcite from Union Springs, Cayuga County, N. Y.

The crystals under consideration were found during the summer of 1899 by Mr. J. M. Clarke, Director of the Geological Survey of the State of New York, and were sent to New Haven for examination. Mr. Clarke had observed that the crystals presented certain features of unusual interest, and it was his wish that they should be described and that the specimens should be deposited in the Yale Collection. The crystals occur in the Onondaga limestone, in a region where slight tectonic disturbances have taken place, giving rise to fissures in which calcite has deposited as vein material. The most interesting feature presented by the crystals is their diversity of habit, shown often on a single hand specimen, and due to different methods of twinning together with peculiarities in the development of certain crystal faces.

Most of the crystals were not well adapted for measurement with the reflecting goniometer, but, using one of the smaller ones, about 5mm in length and 2mm in diameter, it was possible to identify the prominent forms by means of their angles. The small crystals are quite highly modified and their development is represented by fig. 1. The terminal faces are the brightest and best developed, and are those of the common scalenohedron v, $21\bar{3}1$. There was measured for the identification of this form r (cleavage) $\wedge$ v, $10\bar{1}1 \wedge 21\bar{3}1 = 28° 56'$, calculated $29° 1' 30''$. In the zone r, v, and making a very small angle with v is the scalenohedron v_1, $7{\cdot}4{\cdot}\bar{1}\bar{1}{\cdot}3$, which is especially prominent on the crystals from this locality. This form was identified by von Bournon on crystals from Derbyshire and the Dauphiné Alps, and appears as form No. 37, plate 31, of his *Traité de Minéralogie*, published in 1808. The form was identified by its position in the zone r, v and the measurement $v \wedge v_1 = 3° 23'$, calculated $3° 55'$. On the crystals under consideration the faces of the scalenohedron v_1 have a vicinal development, and thus the contrast between them and the better developed faces of the scalenohedron v is generally quite marked. A negative rhombohedron, f_1, truncates the edges of v_1 and appears always as a narrow face with vicinal development from which no reflection could be obtained. A rhombohedron in this

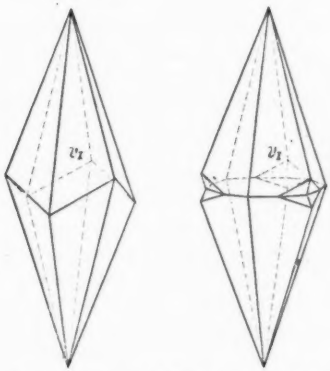


position would have the symbol $0{\cdot}12{\cdot}\bar{1}\bar{2}{\cdot}5$, and is a little steeper than the common rhombohedron *f*, $02\bar{2}1$, which truncates the pole edges of the scalenohedron *v*. The pyramid of the second order γ, $8{\cdot}8{\cdot}\bar{1}\bar{6}{\cdot}3$, was identified by the measurement $8{\cdot}8{\cdot}\bar{1}\bar{6}{\cdot}3 \wedge 8{\cdot}8{\cdot}\bar{1}\bar{6}{\cdot}\bar{3}=25°\ 40'$, calculated 24° 46′, and, further, by its being truncated by the positive rhombohedron *M*, $40\bar{4}1$. This rare pyramid was first identified by vom Rath* on crystals from Andreasberg in the Harz, and, as pointed out by the authors,† this same pyramid is the prevailing form of the siliceous calcites from the Bad Lands of South Dakota. On crystals from Union Springs there is a tendency for the upper and lower faces of the pyramid γ to round into one another, owing to vicinal development, and because of this rounding it was impossible to obtain an accurate measurement between the upper and lower γ faces.

On the majority of the specimens the crystals are not so highly modified as the one just described, but as already stated the variation in habit due to twinning and the unequal development of certain faces, gives to the specimens a peculiar interest. All the types to be described occur on a single specimen having a surface about half the size of one's hand covered with crystals. The crystals on this specimen were not suitable for measurement and therefore no angles will be given, but the forms were evidently like those identified on the small crystal previously described.

Scalenohedral type.—The scalenohedron v_1, $7{\cdot}4{\cdot}\bar{1}\bar{1}{\cdot}3$, fig. 2, is apparently very common at the locality. It should be stated

2 3

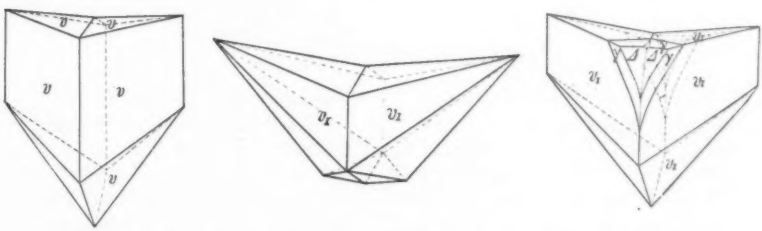


that this form has the same middle edges as the rhombohedron *r*, $10\bar{1}1$, and the common scalenohedron *v*, $21\bar{3}1$, but is somewhat steeper than the latter form. A twinning about the basal plane, fig. 3, is quite common.

* Pogg. Annalen, cxxxii, p. 521, 1867. † This Journal, ix, p. 352, 1900.

Twins, with the rhombohedron e, $01\bar{1}2$, *as twinning plane.*—The habit resulting from this kind of twinning is like that of the well known Guanajuato calcites, fig. 4, described by Pirsson,* and it should also be stated that as early as 1837 Lévy† also described and figured calcite twins of this same type from Streifenberg, Nertschinsk, Siberia. Fig. 4 is analogous to the figures of Pirsson and Lévy, though drawn in a different position, and represents the common scalenohedron *v*, $21\bar{3}1$, drawn with the twinning plane vertical and having a position like that of the side face of a cube, or the pinacoid 010 of any of the three axial systems. This position has been adopted for representing the twin crystals as it gives the best idea of their peculiar development. Fig. 5 represents the scalenohedron v_I,

4 5 6



$7{\cdot}4{\cdot}\bar{1}\bar{1}{\cdot}3$ twinned without distortion, a type which has not been observed on any of the specimens, but the figure is introduced in order to show how, by the extension of the two lettered faces in front and the parallel faces behind, together with the suppression of the four small faces below, the Guanajuato type, fig. 4, results. Most of the Union Springs crystals of the Guanajuato type show in addition to the scalenohedron certain modifications at the reëntrant angle, fig. 6. The faces forming the reëntrant angle are the pyramid of the second order γ, $8{\cdot}8{\cdot}\bar{1}\bar{6}{\cdot}3$, and a rhombohedron designated as Δ, apparently in the zone with v_I and γ, which would cause it to have the symbol $80\bar{8}3$. The surfaces forming the gash or reëntrant angle, however, are curved to such an extent that exact symbols cannot be assigned to portions of them.

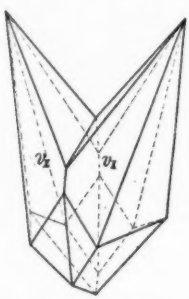
Twins with the rhombohedron f, $02\bar{2}1$, *as twinning plane.*—The rhombohedron *f* is one of the rare twinning planes of calcite, and the habit presentod by the crystals from Union Springs is very striking. The scalenohedron v_I, $7{\cdot}4{\cdot}\bar{1}\bar{1}{\cdot}3$, twinned about *f*, and drawn with the twinning plane vertical, as previously

* This Journal III, xli, p 61, 1891.

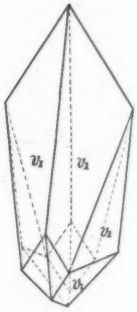
† Description d'une Collection de Minéreaux formée par H. Heuland, vol. i, p. 10, fig. 5, Plate 1.

described, is represented by fig. 7. In the Union Springs crystals representing this twinning law the reëntrant angle at the top wholly fails, and a peculiar, pointed, spear-head devel-

7



8



opment, fig. 8, results from the extension of the two front lettered faces of fig. 7 and the corresponding faces at the back. The crystals observed have always been attached at the lower end. Several crystals of this peculiar type were observed on the specimens sent by Mr. Clarke, and they are said to be quite common at the locality. On a crystal with a broken point the reëntrant angle measured from the rhombohedral cleavages was found to be 35° 38′, calculated 35° 27′.

Lévy, in fig. 6 of the atlas to his work already cited, gives a representation of a crystal from Kongsberg in Norway, of identically the same habit as fig. 8 of this article; however, the habit is apparently a very unusual one, and it is interesting to record it at a new locality.

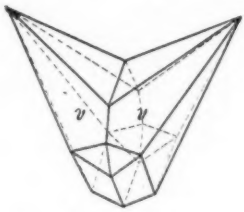
On a single specimen or even at one locality, as a rule, all crystals of a certain mineral have the same or nearly the same habit, resulting undoubtedly from crystallization under uniform conditions, and therefore it seems a matter of more than usual interest to note on a single hand specimen from the Union Springs locality, the occurrence of simple scalenohedrons, fig. 2, and of three distinct types of twinning, figs. 3, 6 and 8. The calcite crystals seem to be all of one generation. Associated with them are a few crystals of dolomite, apparently of later growth.

2. Butterfly Twins from Egremont, Cumberland, England.

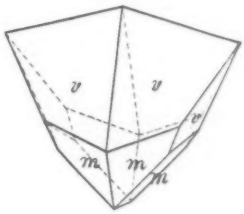
The so-called butterfly twins from Egremont are well-known and are figured in many mineralogies. Lévy in his work, already cited, gives three figures of them, No. 17, 68, and 69 of his atlas. A few words concerning them and new figures

are introduced in the present article for the sake of comparison with the two types of rhombohedral twinning previously described. The twinning plane in these crystals is the rhombohedron r, $10\bar{1}1$, and the common scalenohedron v, $21\bar{3}1$, thus twinned and drawn, as in previous cases, with the twinning plane vertical, is represented by fig. 9. Fig. 10 represents a

9



10



crystal of the butterfly twin type in the Brush collection, and, by comparison with fig. 9, it may be seen that the upper faces of the crystal result from the development of the two front, lettered faces of fig. 9 and corresponding faces behind, to the complete obliteration of the reëntrant angle. The faces at the lower extremity of fig. 10 are those of the prism m, $10\bar{1}0$.

It is a matter of interest to observe how the scalenohedron when twinned as described according to the three rhombohedral laws gives apparently simpler shapes by distortion, or unequal development of some of its faces, than if the distortion had not taken place.

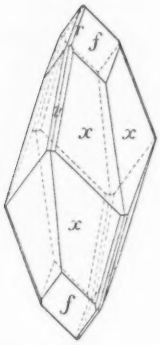
3. Crystals from Pallaflat, Cumberland, England.

A feature of the crystals from this locality, as represented by specimens in the Brush collection, is the prominent development of the negative scalenohedron x, $13\bar{4}1$. This form, as shown by fig. 11, has its shorter pole edges bevelled by the common scalenohedron v, $21\bar{3}1$, and has the same middle edges as the negative rhombohedron, f, $02\bar{2}1$. Fig. 11 was drawn by Mr. W. Valentine of the Sheffield Laboratary. It presents nothing new, and is practically identical with fig. 674 of von Bournon's *Traité de Minéralogie* published in 1808. The figure is introduced in the present article, because by understanding its simple zonal relations, the same forms can be easily identified as they occur on a twin crystal to be described.

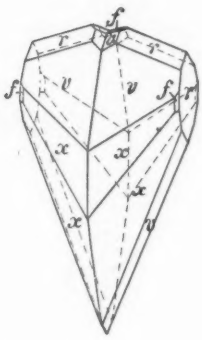
Fig. 12 represents the development of two beautiful twin crystals in the Brush collection, both occurring on the same hand specimen. The twinning plane is the unit rhombohedron, and the development is analogous to that of the butterfly

twins from Egremont, fig. 10. A prominent feature of the twins is the vertical zone r, f and x of the individual to the

11



12



right, extending over the twinning plane to x, f, and r of the left hand individual, and so on around the crystal. Thus with this method of twinning four x faces, two in front and two behind, form as it were a vertical prism, analogous to the prism formed by four faces of the scalenohedron v, fig. 4, when the flat rhombohedron e, $01\bar{1}2$, is the twinning plane.

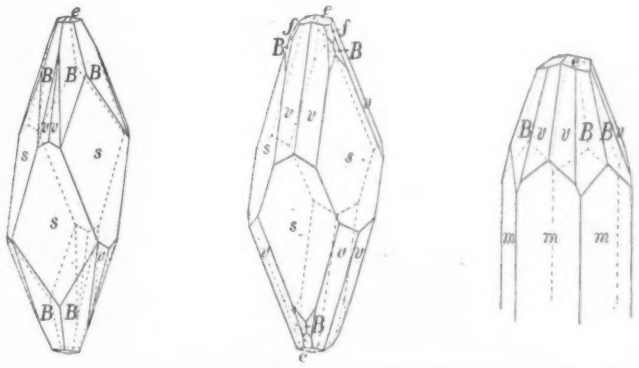
In figs. 4 and 12 the rhombohedral symmetry is not apparent, and the habit is like that of twin crystals of the monoclinic system, having the vertical faces v and x, respectively, as prisms and a pinacoid as twinning plane. The twin crystals represented by fig. 12 are so attached that only a portion of the lower x and v faces are visible.

4. Crystals from the Stank Mine, Lancashire, England.

This locality is represented in the Brush collection by a suite of eleven groups of crystals. A form which appears on all of the crystals, and which seems to be especially characteristic for the locality, is the negative scalenohedron B, $2\cdot8\cdot\bar{1}0\cdot3$, having the same *middle edges* as the rhombohedron f, $02\bar{2}1$. On all of the specimens the faces of the scalenohedron have a decided vicinal character. Some of the specimens are simply groups of scalenohedral points without modifications. Generally, however, as shown by fig. 13, the flat negative rhombohedron e, $01\bar{1}2$, is slightly developed, and long narrow faces of the positive scalenohedron v, $21\bar{3}1$, modify the pole edges, while some portions of the negative rhombohedron s, $05\bar{5}1$, may be seen near the attachment of the crystals. Another prominent type which seems to be common is represented by fig. 14. In

this type of crystal the rhombohedron *s* is prominent and is bevelled by the scalenohedron *v*; the pole edges of *v* are truncated by the rhombohedron *f*, and *B* and *e* appear as slight modifications only. The type of crystal, however, which it is desired especially to call attention to is represented by fig. 15, there being several almost ideally developed crystals of this type in the collection. The peculiar feature presented by the crystals consists in the termination of the prism *m*, $10\bar{1}0$, by twelve faces of almost equal size and shape, thus giving the appearance of a prism terminated by a dihexagonal pyramid. Six of these terminal faces belong to the positive scalenohedron *v*, and the remaining six to the negative scalenohedron *B*, while the negative rhombohedron *e* appears at the end of the crystal. The distinction between the *v* and *B* faces is at

13 14 15

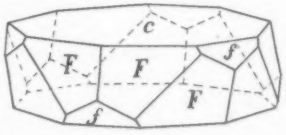


first glance not at all apparent, but the forms may be distinguished by their relative positions with reference to the rhombohedron *e* and by slight differences in their surface markings, the *v* faces being finely striated parallel to their intersection with the unit rhombohedron, while slightly undulating, smooth, vicinal surfaces characterize the form *B*.

5. Crystals from Elæolite-Syenite, Montreal, Canada.

The crystals under consideration are small tabular individuals, fig. 16, measuring about 8^{mm} in diameter, and were found by Mr. W. F. Ferrier of Rossland, B. C., at the Corporation Quarry, Outrement near Montreal. Only a few crystals were found, and one of these was presented to the Brush collection by Mr. Ferrier. A tabular habit is not at all uncommon for calcite, but the crystals deserve brief men-

16



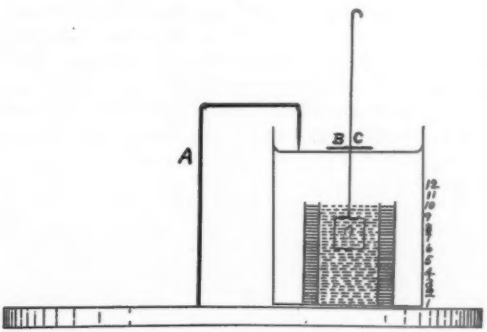
tion because of the peculiar combination of forms. Besides the basal planes only two forms are present, the negative rhombohedron f, $02\bar{2}1$, a very common form, and the positive scalenohedron F, $42\bar{6}1$, a rare form for the species. The scalenohedron F has the same parameter relation on the horizontal axis as the common scalenohedron v, $21\bar{3}1$, but is twice as steep, F intersecting the vertical axis at 6 and v at 3. Fig. 16 was drawn by Dr. H. E. Gregory while a student in the laboratory.

Sheffield Laboratory of Mineralogy and Petrography,
Yale University, New Haven, May, 1900.

Art. XXIV.—*A Method of Measuring Surface Tension;* by James S. Stevens.

In the methods of measuring surface tension which have formerly been employed there seems to be two difficulties: the weights applied to break the tension cannot be added in continuous increments, and they afford a certain accelerating force beside their own mass when they are dropped on to a scale pan; and secondly, it is difficult to apply the pull exactly at the center of inertia of the body used to break through the surface skin. The second difficulty was overcome in a method described by T. P. Hall, where filaments of glass were detached from a liquid surface by weights applied to a scale pan which formed the opposite end of a balance.

1



A, hook gauge; BC, disk; D, sinker.

The method described here is free from difficulties of the above nature. An iron wire is bent into the form of a T (fig. 1) and the cross allowed to float on the surface of water. The body of the T projects a little distance into the center of a coil of copper wire through which a current may pass. The part of the T forming the plunger is adjusted so that its weight is nearly sufficient to break through the liquid surface. A slight pull towards the center of the coil due to the passage of a current will then accomplish this. The system is raised and lowered by a rack and pinion so that it may be placed on the liquid surface as gently as possible.

By means of a continuous resistance the current may be applied in small increments, and the amount required to break through read from an ammeter. When the current is applied the plunger immediately moves to the center of the coil and

the pull is then steadily applied to the center of inertia of the system.

The magnetic force may be calibrated at leisure by use of a balance or it may be calculated from the constants of the coil. This in proper units must be added to the weight of the system.

In some experiments already made by this method a circular disk of thin ferrotype plate was used and a rather heavy sinker of soft iron fastened to its center. The variation of surface tension with temperature in case of distilled water, the effect of adding a drop of oil, the surface tension of a soap solution and the results with disks of different areas have been tested.

In order to test the law of inverse squares a hook gauge was employed so that the height of the water surface, and hence the floating disk, could be adjusted very closely. By means of a scale fastened to the side of the vessel containing the liquid, the weight of the surface could be changed by successive centimeters. If we assume that the force required to break the tension is constant, and if we call the distance between the center of attraction of the coil and the magnetic center of the system attracted, when they are nearest together, x; then $x+1$, $x+2$, etc., will represent other distances used. Let c', c'', etc., stand for currents corresponding to these distances and we have

$$\frac{c'}{x} = \frac{c''}{x+1} = \frac{c'''}{x+2}\ , \text{ etc.}$$

Substituting values and solving we have for a given experiment $x = 6^{cm}$.

Applying the values to other measurements we have 1·88, 1·81, and 1·95 as ratio numbers expressing the value of the same force, namely that required to break through the surface tension.

Very little work has been done with this apparatus and this paper is designed to describe the method rather than announce results.

Orono, Maine.

SCIENTIFIC INTELLIGENCE.

I. Geology and Mineralogy.

1. *The Glacial Gravels of Maine and their associated deposits;* by George H. Stone. U. S. Geol. Survey, Monograph XXXIV, pp. 1–499.—Ever since the early writings of Agassiz on the glacial geology of New England, the "horsebacks" and terraces of Maine have been generally known, but the great extent and remarkable perfection of the glacial deposits is a recent discovery. Prof. Stone's work, extending over a period of thirteen years, has resulted in a series of maps showing the distribution of the water-laid sediments of glacial time over the whole state. The deposits from each glacial stream have been mapped and grouped into some sixty gravel "systems." Each "system" is composed of trunk stream (usually an esker) with tributaries and distributaries (delta branches). Under separate heads a detailed description is given of composition, shape, etc., of each group. The gravel "systems" are usually 10–25 miles in length; the Houlton "system" is 115 miles long and the Katahdin stretches out for 125 miles. The longer "systems" extend for many miles like an artificial roadway carefully constructed, and with the exception of Sweden constitute the finest examples of gravel ridges in the world.

This reconstruction of the river systems of glacial time has been done with great labor, for there are no adequate maps of Maine and much of the region is a succession of swamps and forests. The fifteen maps accompanying the monogram show at once the difficult nature of the work and the remarkable development of the forms of drift in the state. The chapters on Classification and Genesis are valuable not so much because of the theoretical conclusions drawn as for the great mass of detailed description and discussion of the abundant material at hand. Much has been done in glacial geology since the manuscript for this monograph was completed (1889), but we know of no more important contribution to the general discussion of eskers. Besides the treatment of eskers space is given to descriptive and theoretical matter in regard to kames, coast gravels, valley drift and tills. A study of the till and the marine clays was made to determine whether there was an interglacial period in Maine as in the Mississippi Valley, but the evidence was found to point to a single glacial period. H. E. G.

2. *The Illinois Glacial Lobe;* by Frank Leverett. U. S. Geol. Survey, Monograph XXXVIII, pp. 1–797, with 18 maps and 15 illustrations.—This is the most elaborate volume on Glacial Geology yet published and renders accessible the mass of facts gathered during many years of research by a force of geologists under the direction of Prof. Chamberlain. The problem before Mr. Leverett was the investigation of the complicated phenomena

arising from the movements and deposits of the successive advances of the ice front in the Lake Michigan region. Not only detailed study but more refined methods of investigation were demanded, and the development of these methods will be useful in all future glacial work. The various drift sheets are described in detail under the following heads: 1. The Illinoian Drift Sheet—the most extensive in the region, which was preceded by an interval of deglaciation (Yarmouth) and followed by the Sangamon interval of deglaciation. 2. The Iowan Drift Sheet, in the discussion of which the whole loess problem is gone over and conflicting views compared, without however arriving at a definite general conclusion as to the origin of the loess. The Iowan deposits are overlaid in places by the "Peorian soil" of another interval of deglaciation. 3. Two Wisconsin Drift Sheets complete the series.

Perhaps the most generally interesting part of the monograph are chapters XI and XII, dealing with beaches of Lake Chicago and the Chicago outlet and with the many cases of reconstructed drainage throughout the drift-covered area. Each stream is treated separately and the past and present conditions of its drainage basin is discussed. In Chapter XIV all the reliable well records of Illinois are given and conclusions drawn as to character of soil, relation of drift to water supply, etc. From the well data and from comparison of the drift areas to adjoining driftless areas the average thickness of the Illinois drift sheet is given as 100 to 130 feet. H. E. G.

3. *The Geography of the Region about Devils Lake and the Dalles of the Wisconsin with some notes on its Surface Geology;* by ROLLIN D. SALISBURY and WALLACE W. ATTWOOD. Wisconsin Geol. and Nat. Hist. Survey, Bulletin No. 5, pp. 1–146. 85 plates and illustrations.—This bulletin of the Wisconsin Survey begins an educational series designed primarily for use in the schools. It marks the beginning of a plan to make the work of the geological surveys directly useful to all intelligent people of a state instead of to the few specialists. The volume was evidently prepared by skillful teachers, for the region chosen for description is clearly marked and typical and interesting and the plan of presentation is that of the most successful instructors. Part I is a description of the topography of the area—the quartzite ridges and the sandstone plains. Part II deals with the history of the topography. The origin of the rocks which show themselves at the surface is explained and their scenic features which result from erosion are described. The glacial period and its effect on topographic form is treated of easily. In connection with each division of the subject there is given just enough theoretical matter to put the abundance of local facts in proper perspective. The volume contains no geological facts regarding this interesting region which have not been published before, but it is timely and valuable as a plan for presenting a geographical subject to schools and as a suggestion to state surveys. H. E. G.

4. *The Moraines of Southeastern South Dakota and their Attendant Deposits;* by JAMES E. TODD. U. S. Geol. Survey, Bulletin 158, pp. 1–168.—This report is a description of the Pleistocene deposits of the Dakota-Nebraska region. The deposits are described as a first or outer moraine which extends down to the Missouri River, a second moraine bordering a region farther north, and various forms of drift outside the moraines. The drift region beyond the outer moraine is largely loess and Prof. Todd describes at some length the distribution character of these interesting deposits. The Missouri River is believed by the author to have been largely excavated since the ice age and, furthermore, that the river is still deepening its trough.

H. E. G.

5. *Preliminary Report on the Copper-bearing Rocks of Douglas County, Wis.;* by U. S. GRANT. Wisconsin Geol. and Nat. Hist. Surv. Econ. Series, No. 3, Bulletin VI. Pp. 55, maps and plates. Madison, 1900.—This work has for its purpose a study of the copper-bearing rocks of the Keweenawan series in the region southeast of Duluth and Superior, the so-called Douglas Copper Range, to ascertain the character and value of the copper deposits. The rocks and the occurrence of the ores are quite similar to what is found in the well-known region of Keweenaw Point. The promise of valuable deposits is not, however, very great, the copper being scattered so much as to make in general very lean ores. While the value of the work is chiefly local, it will also prove of interest to all who are interested in the origin and occurrence of ore deposits. L. V. P.

6. *Bulletins of the Geological Survey of Finland, No. 9. Esquisse hypsometrique de la Finlande;* by J. J. SEDERHOLM. Pp. 17, 8vo. Helsingfors, 1899.—This is a short description of a relief map of Finland on a scale of 1 : 2,000,000, in which the main features of the topographic relief are brought out and described.

No. 10. *Les depots Quaternaires en Finlande,* by J. J. SEDERHOLM (pp. 28, 1899). This little work contains a brief but very good description of the glacial deposits of Finland and is accompanied by an excellent map on the same scale as the preceding one. The differences of relative level of land and sea at different times, the movement of the ice and the remarkable and celebrated osar, colossal glacial embankments crossing the country in long lines and well shown on the map, are described and discussed.

No. 11. *Neue Mitteilungen über das Ijolitmassiv in Kuusamo,* by V. HACKMANN (pp. 45, 8vo, 1900). Ijolite is a name given by Ramsay and Berghell to the rock forming a mountain mass composed of pyroxene and nephelite and of granular structure. Recently Hackman has studied this occurrence in the field and gives a full description, showing it to be a complex of alkaline rocks ranging from ijolite through essexite into pyroxene-syenite. The ijolite is the main type. Several new analyses are given and the whole is an interesting contribution to the petrography of the alkaline rocks. L. V. P.

7. *Analyses of Rocks, Laboratory of the U. S. Geological Survey, 1880 to 1899*; F. W. CLARKE. Bull. 168, U. S. Geol. Surv., 1900, pp. 308. This is a new edition of Bulletin 148 of the Survey publications, containing a large number of new analyses, chiefly executed by W. F. HILLEBRAND and H. N. STOKES. All told, some 1,400 analyses of rocks, clay, soils, etc., are given. The order of the analyses has been changed, the more important constituents being given first, as is usual with many petrographers. This makes the analyses much more convenient for use. As before, the arrangement is geographical. The former chapter on rock analysis by Hillebrand is omitted and it is stated that this, in an enlarged form, will soon appear as a separate bulletin. One cannot but be impressed by the enormous amount of painstaking, careful and skillful work represented by these analyses, so complete and so detailed. From no other source could such a mass of similar analyses be gathered, and they doubtless represent the most important work done in American chemical geology.

L. V. P.

8. *The Bjurböle, Finland, Meteorite.*—Portions of this meteorite are now on exhibition in the Finland pavilion at the Paris Exposition. The fall took place March 12, 1899. The mass, which had a total weight of about 340 kilos, fell into the Gulf of Finland, making a hole about nine yards in diameter in the ice (which had a thickness of about 28 inches) and penetrating the submarine clay to a depth of six yards. The removal of the mass has been a matter of considerable difficulty and was accomplished only in sections. The portions on exhibition at Paris are the largest secured and weigh 83 and 22 kilos respectively. The interior of the stone is gray with yellowish spots. The exterior is covered with a black crust. Prof. Stanislas Meunier gives in a recent issue of "Le Naturaliste" the results of a detailed study of the meteorite. He describes it as friable in texture and in structure of the variety to which he applies the term öolitic. The mineralogical composition is largely chrysolite and pyroxene, with which are associated grains of nickel-iron, iron sulphide and chromite. Sp. gr. = 3·54. Chondrules varying in diameter from ·5 to 2·5^{mm} are easily separated. They are of several types, which are fully figured. The most remarkable are those of a fibrous, probably feldspathic, mineral often enclosed in a metallic shell, and those containing porphyritic crystals of augite. The meteorite is classed by Meunier as belonging to his Type 38, Montrejite. The stones of Hessle, Aussun, Prairie Dog Creek and Searsmont will be remembered to be other examples of this type.

O. C. F.

OBITUARY.

Professor G. H. F. ULRICH, F.G.S., Director of the School of Mines of Otago University, Dunedin, New Zealand, died on May 26, at the age of seventy years. By his active investigations, first in Victoria and later in New Zealand, he contributed much to the knowledge of the Mineralogy and Geology of those countries.